Vol. 13, No. 4 April, 1957

LUBRICATION ENGINEERING

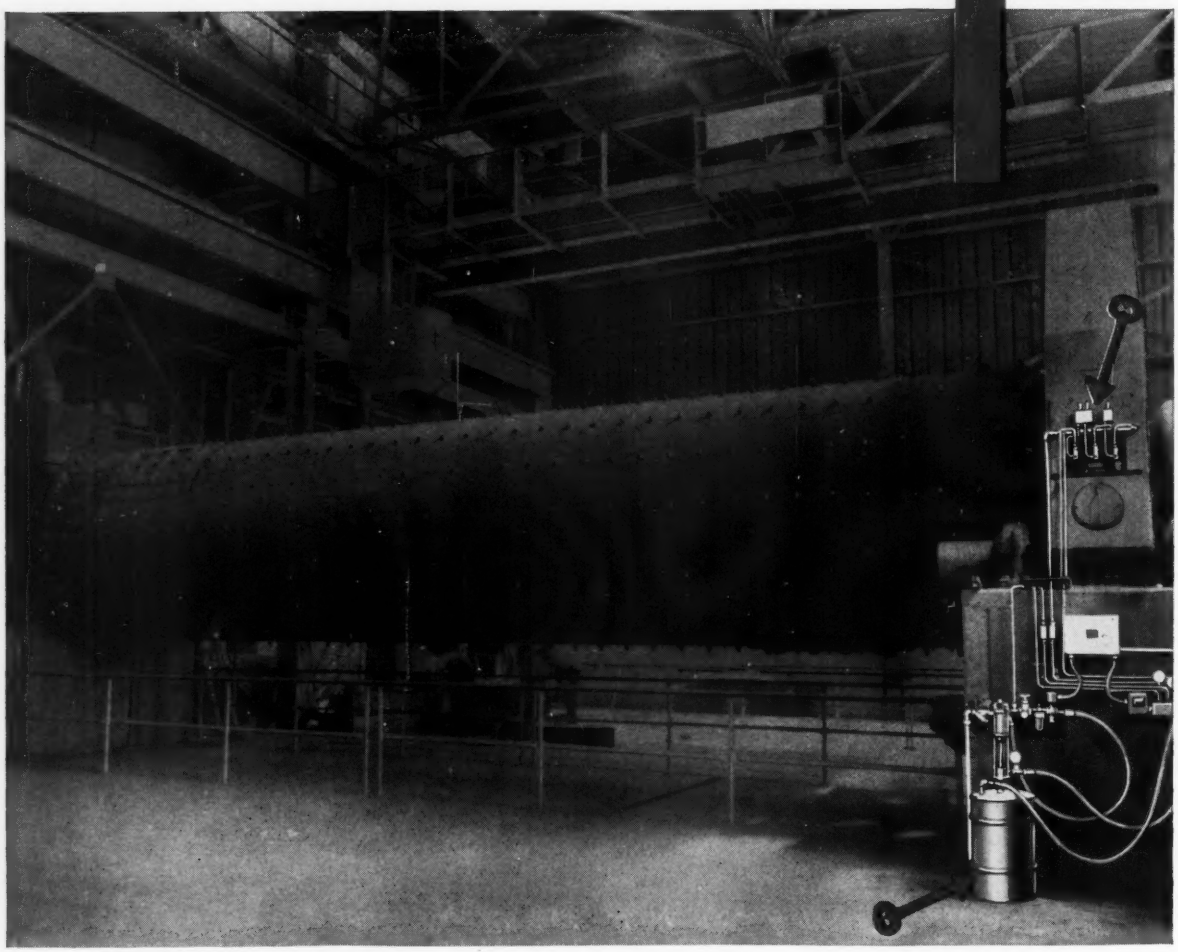
RESEARCH APPLICATION EDUCATION MAINTENANCE

Detroit Skyline at Night
(ASLE 12th Annual Meeting & Exhibit Issue)

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

Farval Spray Panel lubricates ball mill at Canada's farthest north cement plant

FARVAL—
Studies in Centralized Lubrication
No. 198



KEYS TO ADEQUATE LUBRICATION— One of five 2-compartment 8′ x 37′ Allis Chalmers raw mills at Inland Cement Company Limited. Note Farval Automatic Spray Lubrication System at right above. Controlled by a timer, Farval sprays high viscosity grease on gear and pinion every 6 minutes.

● Lubrication of the ball mills for this most northerly cement plant is sure, safe and economical. The main gears and pinions are protected by a Farval system of automatic spray lubrication.

This mill is located in the $12,500,000 cement plant built recently at Edmonton, Canada, and now operating at near capacity to serve the expanding industry centering in Alberta's booming oil fields.

Farval automatic lubrication also is growing—in wider and wider use throughout industry and in ever increasing benefits to users. Hundreds of spray lubrication systems have been installed on gears and sliding surfaces. Millions of bearings are served by Farval manual and automatic systems.

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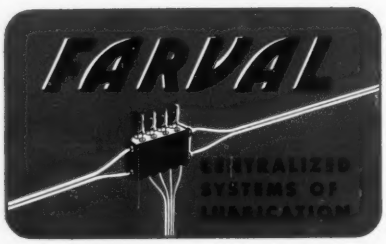
Ask us to mail Farval Bulletin 26-R. And a representative will call at your convenience. The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.



Affiliate of The Cleveland Worm and Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Volume 13, No. 4

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LUBRICATION ENGINEERING is published monthly by the American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Illinois. Current-year single copies 75c; previous-years' single copies, if available, $1.00. Annual subscription $6.00 in the United States and Canada, $7.00 in all other countries. Copyright 1957 by the American Society of Lubrication Engineers. ASLE will not be responsible for statements or opinions presented at its meetings or printed in its publications.

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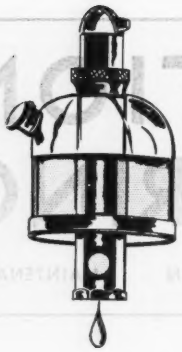
Engravings by **Leader Engraving Co.**, Rochelle, Ill.
Printed by **Publishers Printing Co., Inc.**, 112-116 E. Chestnut St., Louisville 2, Ky.
(Second class mail privileges authorized at Chicago, Ill.)

The Sight Glass



Highlights of Articles Scheduled for Coming Issues!

Thermal Conductivity of Aircraft Engine Lubricants at Low Temperature

Thermal conductivities and thermal diffusivities of a representative aircraft-gas-turbine lubricant and a representative piston-engine lubricant were determined over a temperature range of -100° F to 80° F. Average results of 0.75 Btu per hour °F ft for the turbine lubricant vs 0.090 Btu per hr °F ft for the piston lubricant indicate the considerable differences in thermal conductivity between the materials and the hazard in applying existing empirical relationships. The thermal conductivity of the turbine lubricant varied linearly with temperature, while the thermal conductivity of the piston engine lubricant varied irregularly due to wax separation.

Specific Heats of Aircraft Engine Lubricants at Low Temperatures

The design and performance evaluation of aircraft lubricating oil systems depends on a knowledge of the thermal properties of the lubricants. This is the first of a series of papers from a general research program undertaken to satisfy the need for information on thermal properties at low temperatures.

Synthetic Ester Lubricants

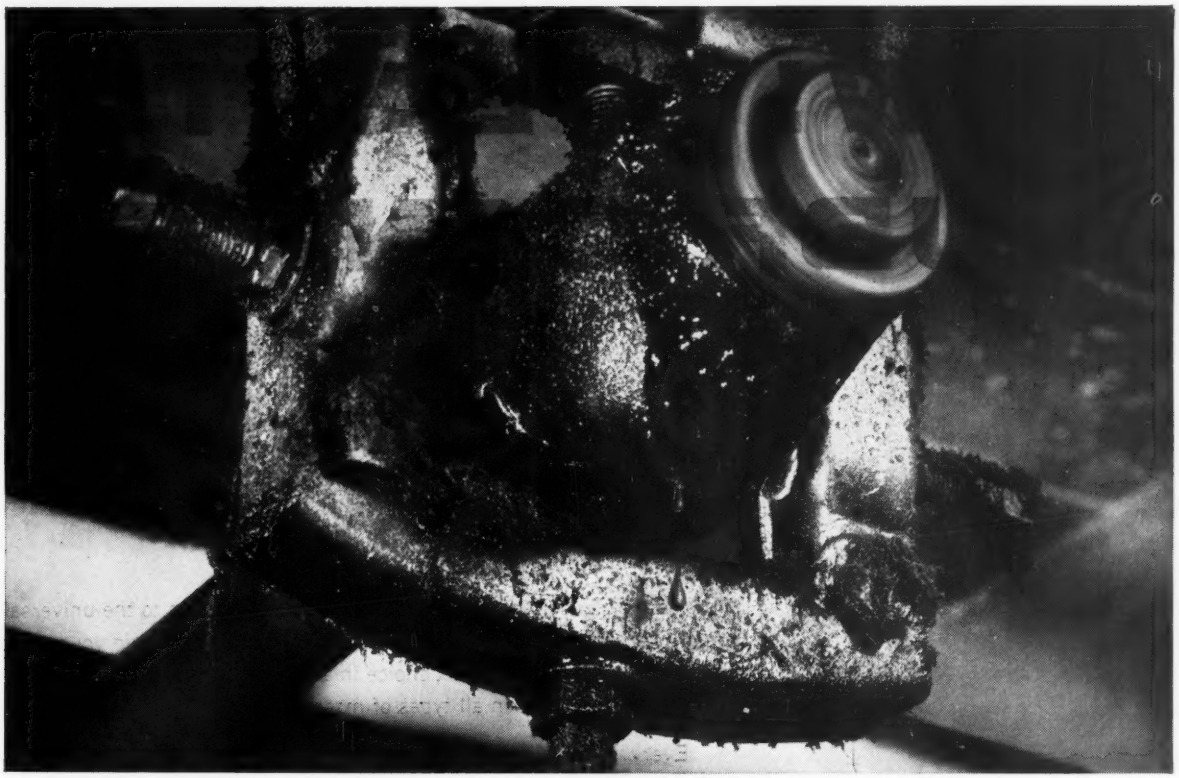
Synthetic esters have properties that make them good lubricants under conditions too severe for mineral oils. Early research in Germany led to commercial production, a good part from polyhydric alcohols and monobasic acids. Development in Britain and the USA concentrated on esters derived from monobasic alcohols and dibasic acids. The esters described in the paper improve the lubricity of silicone oils as well as mineral oils.

Use of Rolling Contact Bearings in Low Viscosity Liquid Metal Lubricants

Tests were conducted on rolling contact bearings submerged in and lubricated by either liquid sodium-potassium alloy or liquid sodium to determine the effect of thrust load on the bearing with respect to bearing life. Various materials of construction and bearing design were used, and the effects of these variables were measured.

Numerical Solution of Reynolds' Equation for Sector Thrust Bearings

A method of solving the Reynolds' equation using digital computer techniques has been developed to predict sector bearing performance. The results compare favorably with experiment and known analytical solutions. The investigation indicates that good design criteria may be established for sector thrust bearings with arbitrary geometries, and possibly very accurate predictions may be obtained if the Reynolds' and energy equations can be solved simultaneously by this technique.



IT'S EASY to reduce annoying and expensive oil leakage like that shown here. The simple act of switching to a Suntac oil – *without making any other changes* – can cut leakage an average of 35%...sometimes 90%!

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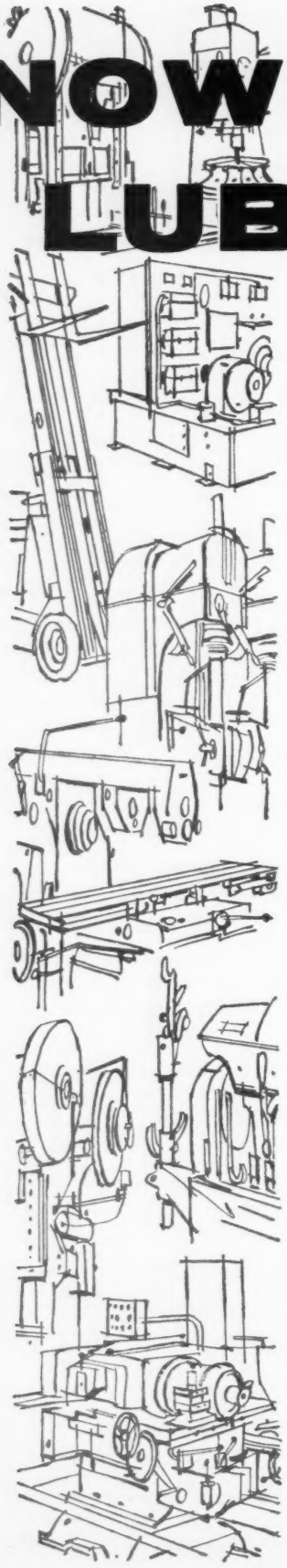

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LUBRICATION ENGINEERING

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The Underlying Reason

Committees and program chairmen often ask, "Why is one meeting successful, another a failure?" Various answers can be given, some to rationalize the situation, others as a result of surface analysis. Few, however, have sound basis.

The 1956 Joint Meeting with ASME at Atlantic City has been thoroughly analyzed by the Joint Lubrication Conference Planning Committee. 396 questionnaires were sent to persons attending the Conference. These questionnaires requested the individual to comment upon various new features presented during the October meeting. Approximately 73% of the questionnaires were returned, and using IBM equipment the Committee was able to determine that the biggest incentive to attendance at a technical meeting was interest in a specific topic on the program. Use of the reporter session technique to present a large number of papers in a very limited amount of time was very well received. The preference was 153 to 43 favoring one Reporter Session in the 1957 Conference. One hundred fifty-six persons indicated enjoying the Reporter Sessions.

Location of a technical meeting, although a factor, should not prohibit good attendance at a well-planned and interesting meeting. Answers indicated 189 individuals plan to attend the Toronto Conference, and only 51 indicated Toronto as being too far to travel to attend a well-planned program.

Individuals attending technical meetings such as the October Conference, favor obtaining copies of the papers presented as a part of their registration fee by a ratio of 251 to 28; even at increased cost of registration, the ratio of answers favoring obtaining copies of papers as a part of the registration fee was nearly four to one.

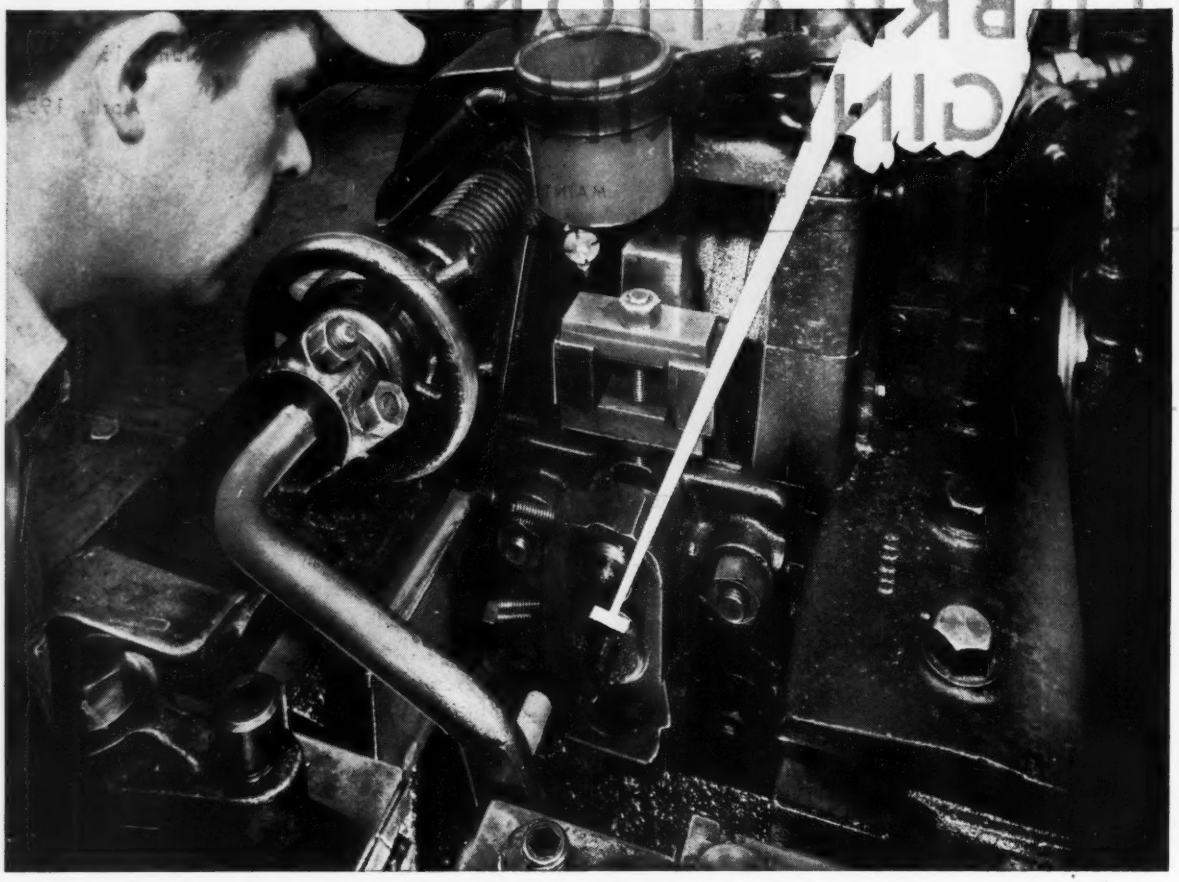
Conference attendees prefer experimental papers. By rating the response to a question defining the type of paper preferred, the following average ratings were obtained (1.0 indicates everyone rated this type of paper first choice, whereas 3.0 indicated everyone had rated the choice third): Review, 2.3; Experimental, 1.35; Theoretical, 2.4.

Questionnaires returned from 145 individuals indicated suggested session topics or papers. The response from these questionnaires indicates high level interest by non-members of the Society, as well as members. The comments may be summarized as follows: allow more discussion time for each session, even if this entails the presentation of fewer papers; schedule a social hour or cocktail party to assist attendees in becoming acquainted; improve visual aids and oral presentations by the authors; eliminate delay in the receipt of papers by mail after the conference.

In summarizing the factors most important in determining the attendance at a technical meeting as represented by the Joint Lubrication Conference, program quality ranks first. A convenient location appears to be of secondary importance.

Lubrication Engineering commends Mr. A. C. West of the California Research Corporation for conducting and analyzing the questionnaire treating the 1956 Conference. Information developed as a result of this questionnaire technique will be useful in guiding the Joint Lubrication Conference Planning Committee with future conferences of still higher quality and further improved technical content. rdm.

A Touch here does so much



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Section News

BALTIMORE, March. On March 20, the ASLE Baltimore Section sponsored a 1-day educational course in practical lubrication covering such subjects as "Principles of Lubrication," by J. E. Buchanan (Socony Mobil Oil Co.), "Application of Lubricants," by A. E. Cichelli (Bethlehem Steel Co.), "Handling of Lubricants," film presented by J. P. Kellogg (Alemite Co. of Maryland), "Properties of Lubricants," by M. M. Gurgo (Esso Standard Oil Co.), and "Practical Plant Lubrication," by C. R. Hand (Bethlehem Steel Co.). (Submitted by C. J. Devries, Sec'y.)

BOSTON, January meeting. A. Lewis, Alpha Molykote Corp., presented a paper entitled "Dry Film Lubrication for Extreme Temperatures."

February & March. Six Monday evenings, from February 11 thru March 18, the ASLE Boston Section sponsored a special course in "Lubrication for Industry" at the Massachusetts Institute of Technology, covering such topics as (1) Lubrication Review, (2) Gear Lubricants, (3) Anti-Friction Bearings, (4) Hydraulic Systems, (5) Lubricants, and (6) Setting Up a Lubrication Program.

April 24. A plant tour of the Scott Paper Co., Waterville, Maine, is scheduled for the afternoon, to be followed by an address in the evening entitled "Paper Mill Lubrication" by B. Dunham, Sun Oil Co. (Submitted by E. G. Jackson, Sec'y.)

BUFFALO, February. E. W. Fisher, Product Engineering Manager for The Garlock Packing Co., presented a paper entitled "Packings for Fire-Resistant Fluids." (Submitted by J. A. Eckardt, Sec'y.)

CHICAGO, February. Annual "Ladies Night," featuring Dr. Herd's famous "Fire Magic" lecture demonstration. (Submitted by E. W. Drummond, Sec'y-Treas.)

Awarded Special Certificates. At the February meeting of the ASLE Northern California Section, Dr. E. R. Booser (ASLE President) presented special certificates commemorating ten years' membership in the ASLE Northern California Section to the following charter members (pictured above, from left to right): W. G. Beggs, P. M. Ruedrich, G. A. Durham, E. B. Lien, A. S. Horwitz, J. A. Edgar, R. G. Larsen, C. A. Winslow, R. Y. Martin, and H. T. Graham. Three other eligible candidates, H. G. Isbell, G. A. Olsen, and S. K. Talley, were unable to attend and their certificates were mailed to them.

CLEVELAND, February. C. A. Sluhan, Master Chemical Corp., presented a paper entitled "Cutting & Grinding Compounds," discussing chemical compounds used as cutting and grinding lubricants, and cutting and grinding compounds based on petroleum oils. (Submitted by G. L. Smith, Sec'y.)

DULUTH/IRON RANGE, February. C. Oldenburg, Oronite Chemical Co., presented a paper entitled "Development & Use of Additives in Modern Industrial & Automotive Oils," followed by R. O. Erickson (Shell Oil Co.), ASLE Area Representative, who presented the Section with its official charter. (Submitted by C. D. Johnson, Sec'y.)

LOS ANGELES, March. W. E. Thill, Federal-Mogul-Bower Bearings, Inc., presented a paper entitled "Sleeve Bearings & Engine Life," discussing ideal bearing installation, lining materials, installation problems, and causes of short bearing life. The Section awarded a one-year subscription to "Lubrication Engineering" as a guest door prize. (Submitted by R. F. Connelly, Sec'y-Treas.)

TWIN CITIES, February. C. Oldenberg, Oronite Chemical Co., presented a paper entitled "Development & Use of Additives in Modern Industrial & Automotive Oils." (Submitted by C. H. Sweet, Sec'y.)

It's Toronto in '57

ASLE-ASME

4th Lubrication Conference

October 7-8-9 Royal York Hotel

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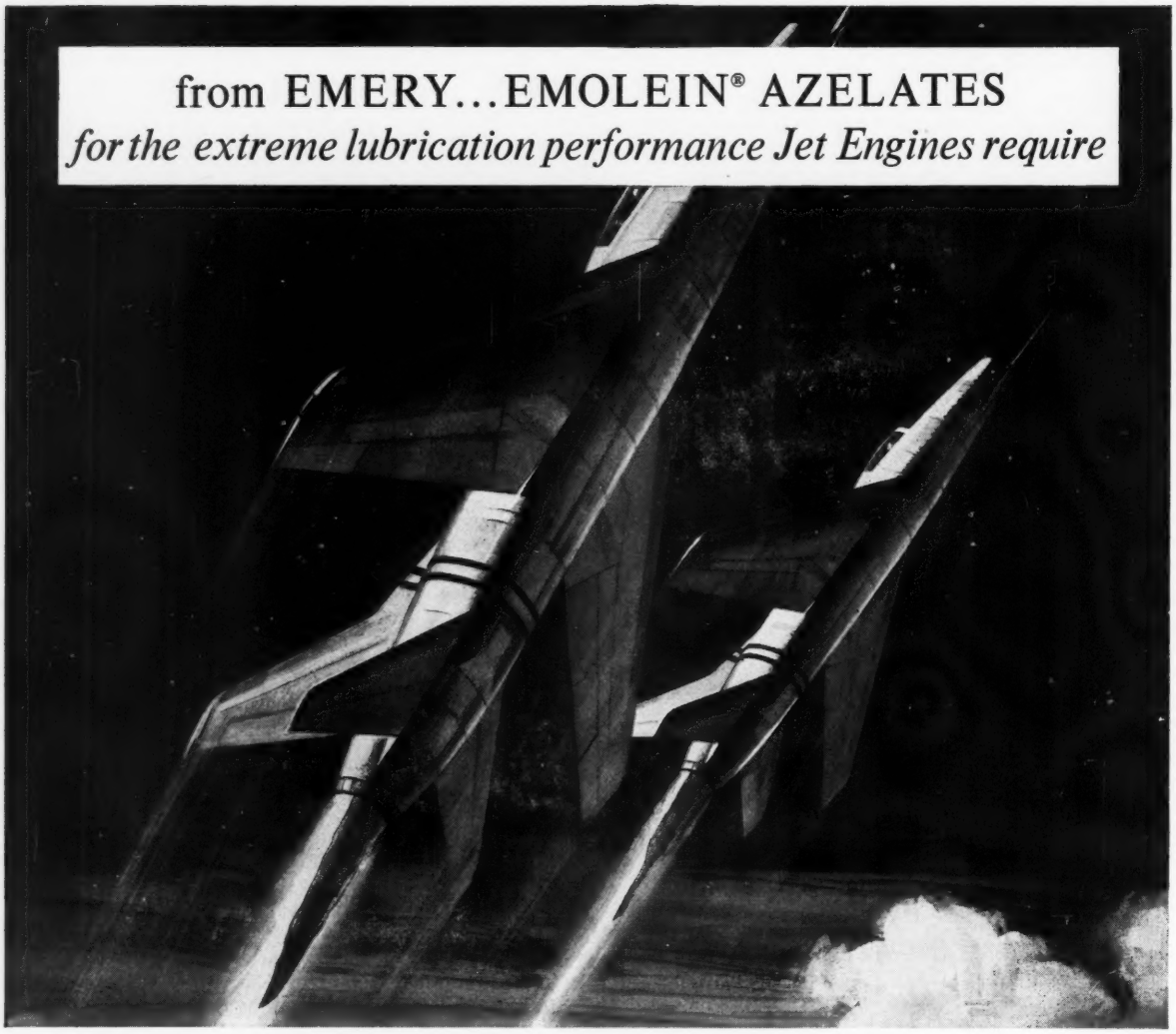

MEETS BOTH MILITARY AND CIVILIAN REQUIREMENTS

Synthetic lubricant fluids that meet both military (Mil-L-7808-C) and civilian specifications are now being compounded from Emolein Azelates (diesters).

The excellent performance of these new diesters, Emolein 2957 di-iso-octyl azelate and 2958 di-2-ethylhexyl azelate in lubricants designed to meet the extreme heat and cold performance qualities required by jet engines, is attributed to the following combination of properties:

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Application in other synthetic lubricants

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Mail coupon below for full technical information.

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Current Literature

"Tubing System Data," Catalog File No. 4305, contains information including charts and tables to aid in proper selection as to size, wall thickness, and material for various operating conditions. Factors considered are flow requirements, pressures, severity of service, and temperatures. (The Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, Ohio.)

"Cutting Fluids," a 19½-minute sound-on-film color motion picture recently released by The Texas Co., shows how cutting fluids work to cut down the harmful effects of heat and friction created during the metal-cutting process. Results of proper use of cutting fluids include improved work finishes, longer tool life, higher cutting speeds, and increased production. After a basic discussion of how a cutting tool works, the film is divided into two parts: cutting oils, and water-based emulsions (solubles). "Cutting Fluids" is a brief, clear, basic summary of present-day knowledge on the role of coolants in metalworking practice. The film is intended to be shown to plant superintendents, shop foremen, methods engineers, and others concerned with metal-machining operations. (For further information, write: The Texas Co., 135 E. 42nd St., N. Y. 17, N. Y.)

Employment Practices Criteria. Printed copies of the employment practices criteria adopted by the National Society of Professional Engineers are now available. Printed in check-list format, the criteria cover specific categories of engineering career development. The criteria suggest the responsibilities of the employer to his professional employees, and the latter's responsibilities to the employer. Topics included are recruitment, indoctrination, professional development of the individual, salaries, engineering titles, personnel practices, and termination policies. (National Society of Professoinal Engineers, 2029 K St., N.W., Washintgon 6, D. C., price 25c.)

"Keystone Specialized Lubricants for Contractor Equipment," dealing with special lubricants for contractor equipment used in earth moving, strip mining, quarrying, road building, excavating, logging, dredging, erecting, and allied fields, describes the application of Keystone grease and oil to 24 different types of heavy equipment. Fourteen photographs illustrate these applications. Two specification charts are presented: (1) a chart of "semi-solid" lubricants that gives working range, melting point, penetration, moisture repellence and body characteristics, and (2) a chart of "liquid" lubricants that lists such data as flash and cold tests, SUV @ 100° F., SUV @ 210° F., and SAE numbers. (Bulletin BU-58, Keystone Lubricating Co., 3100 N. 21st St., Philadelphia 30, Pa.)

"Trends '56," the second edition of an analysis of passenger car lubrication recommendations, pictures the trend of lubrication service requirements of all U. S. cars over the last fifteen years. Of particular interest for sales personnel, engineering staffs, and those engaged in the production and marketing of automotive service products, the publication outlines the progress made in the service field resulting from changes both in automotive engineering design and in petroleum products used in automotive service. Contents cover crankcase lubrication and other engine services, in addition to transmission, differential, and chassis lubrication. (The Chek-Chart Corp., 33 E. Congress Pkwy., Chicago 5, Ill., price $2.50.)

"1957 Reference Guide to Dow Corning Silicones" Almost 150 commercially available silicone products are described in this year's catalog, including several which were developed within the

(Continued on p. 246)

NEW...
EMERY 3033-S
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a new-type diester base for synthetic lubricants

Emery 3033-S is a new-type dipropylene glycol diester based on pelargonic acid, a unique, C_9, saturated, monobasic acid.

It is currently in use or under test in the following three areas: 1) Synthetic greases for spec. Mil-G-3278-A Low Temperature Aircraft Grease; 2) Low-cost blending component for synthetic low-temperature lubricating fluids meeting Mil-L-7808 C; and 3) synthetic lubricant base fluid for civilian lubricants in aircraft, automotive and specialty uses.

Since 3033-S is based on a relatively low-cost acid, pelargonic acid, long-range economics are favorable. Also, availability is not contingent on strategic, imported raw materials since pelargonic acid is made from abundantly available domestic fats and oils.

Though 3033-S is in a development stage, it is available in tankcar quantities on reasonable notice.

Mail coupon below for Technical Bulletin titled "Emery 3033-S Lubricant Ester" for complete characteristics and performance data in synthetic greases and fluids.

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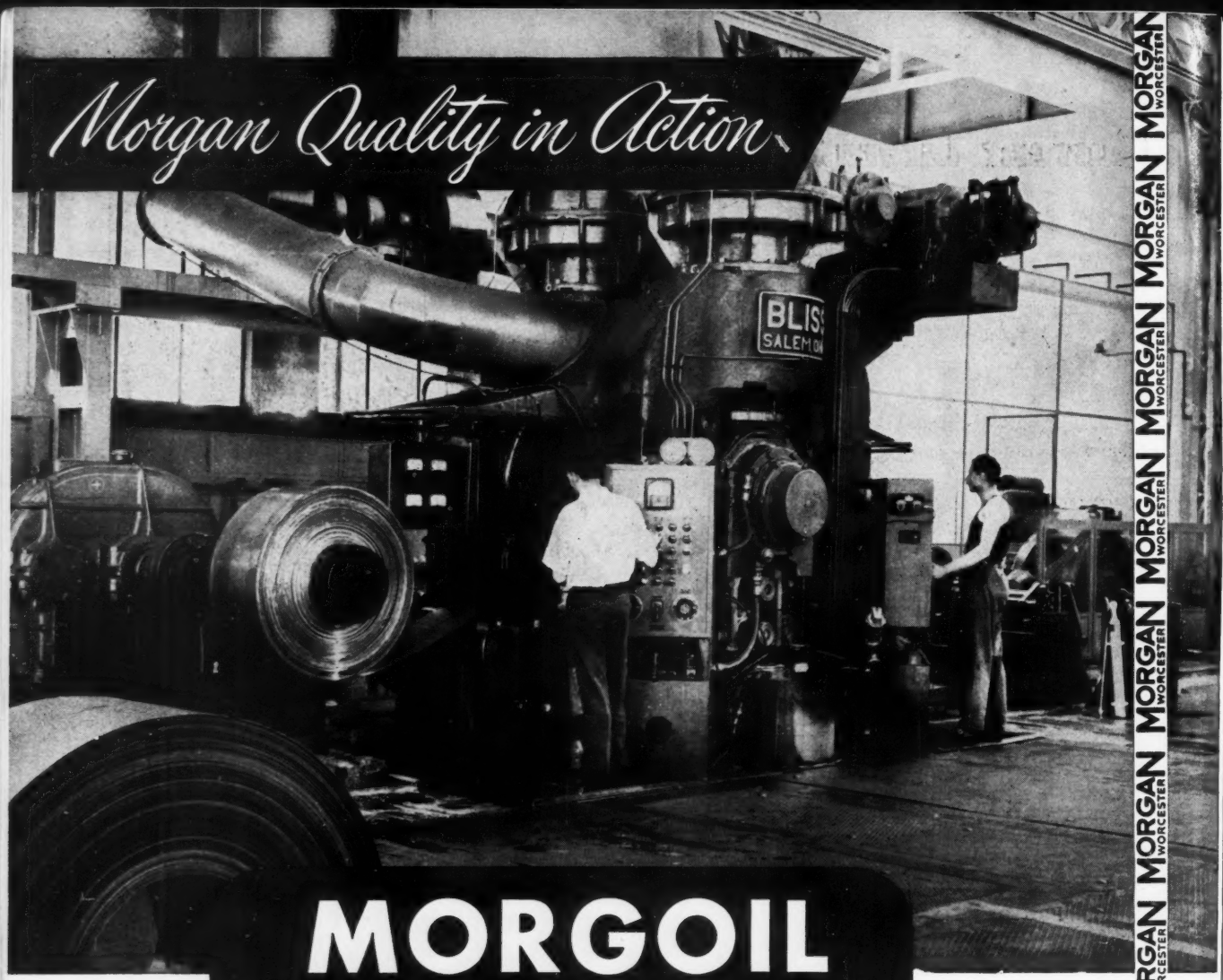

MORGOIL
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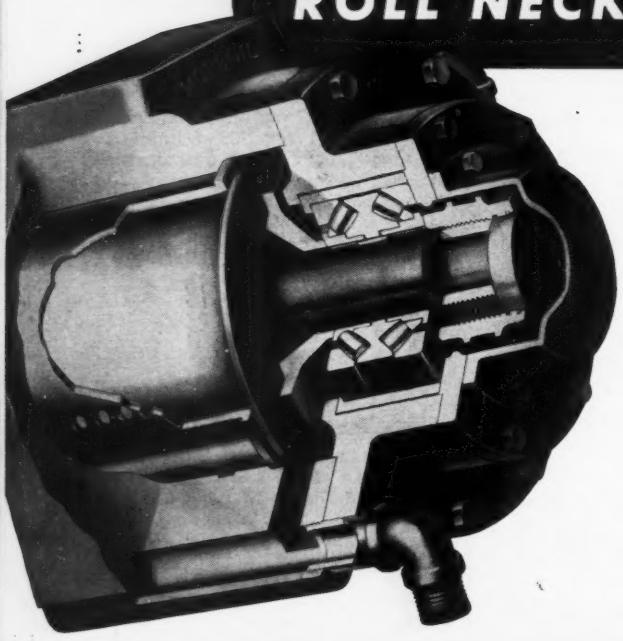

These 26″-90 MORGOIL Bearings are operating in a 10½″ & 30″ x 30″ single stand four high reversing cold mill at Lombarde Falck in Milan, Italy. Hot mills or cold mills, ferrous or nonferrous, at home or abroad, MORGOILS give the best roll neck bearing performance at the lowest cost.

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Personals

The Franklin Institute, Philadelphia, Pa., has announced the promotion of **G. M. Robinson** (ASLE Philadelphia Section), formerly a Senior Staff Engineer, to Chief of the Friction & Lubrication Section of the Mechanical Engineering Div.

V. P. Mahon, Sales Representative for the Lunkenheimer Co., Cincinnati, Ohio, has been transferred from Chicago to Houston, Tex.

Battelle Memorial Institute, Columbus, Ohio, has announced the following appointments: S. L. Fawcett as Assistant Manager of the Dept. of Physics, and W. H. Goldthwaite as Chief of the Engineering Mechanics Div.

The Sharples Corp. has announced newer and larger Cleveland, Ohio, offices at 14700 Detroit Ave.

R. S. Ringheim has been appointed Director of Marketing & Economic Research for Foster D. Snell, Inc., New York City, an organization of consulting chemists and chemical engineers. His duties will include organizing and writing major market and technical surveys for the chemical and related industries.

The Aro Equipment Corp., Bryan, Ohio, has appointed A. P. Sheehy as Industrial Sales Representative in the New England States, with headquarters in Boston, Mass.

Consolidation of the Princeton, N. J., office with the Cleveland, Ohio, facilities of Horizons Inc. has been announced, together with the election of K. M. Bartlett as President of the company, and the appointment of C. J. Strickler as Section Head of organic chemistry in the Chemistry Dept.

R. N. Hoh has been appointed Western Sales Manager of industrial chemicals for American Potash & Chemical Corp., Los Angeles, Calif.

The E. C. Swift Co., 3537 Lee Rd., Cleveland, Ohio, has been named representative for the sale of Purolator's lines of bulk and industrial filters in fifteen counties of Northern Ohio.

The office of Ditzen Engineering & Sales Co., exclusive representative in Northern California for Rivett Air & Hydraulic Valves & Cylinders, has moved to 6002 Telegraph Ave., Oakland.

Mildred Hunt has joined the American Lithium Institute, Inc., Princeton, N. J., as Research Librarian, responsible for organizing a central research library to serve the industry through the correlation and dissemination of information pertaining to applications and developments in the field of lithium and lithium compounds.

Jefferson Chemical Co., New York City, has announced the appointments of G. H. Kahl, K. L. VanderVoort, and J. G. Sibley, as Sales Managers of the company's New York, Chicago, and Charlotte Districts, respectively.

G. A. Darsie has been appointed Eastern District Sales Manager for the Silicone Products Dept., General Electric Co., with headquarters at 254 Elizabeth Ave., Newark, N. J.

The Texas Co., New York City, has announced the appointment of G. Herzog as an Assistant General Manager of the Research & Technical Dept., and the appointment of B. D. Lee as Manager of the company's newly established Exploration & Production Research Div. in Bellaire, Tex.

J. L. Cullen has been named Assistant Sales Manager of the hose division of Flexonics Corp., Maywood, Ill.

Acheson Colloids Co., Port Huron, Mich., has announced the appointment of W. D. Signer, Jr., as Service Engineer for the company's Rochester, N. Y., offices located at 662 Monroe Ave., where he will serve Western & Central New York and Erie County, Pa.

Book Reviews

Part 5: Fuels, Petroleum, Aromatic Hydrocarbons, Engine Antifreezes, a 1956 Supplement to "Book of ASTM Standards"; American Society for Testing Materials, 1916 Race. St., Philadelphia 3, Pa.; 320 pages, price $4.00.

To keep up-to-date the triennially published "Book of ASTM Standards," the American Society for Testing Materials issues Supplements in the intervening years to each part of the Book. The 1956 Supplements, issued in seven parts, give specifications, tests, and definitions in their latest form which either were issued for the first time in 1956 or revised since their appearance in the 1955 Book.

"Part 5" includes 75 standards covering measuring and sampling petroleum and petroleum products; crude petroleum; motor and aviation fuels; engine tests for rating fuels; petroleum solvents and naphthas; industrial aromatic hydrocarbons; diesel fuels, distillate burner fuels, kerosene and illuminating oils; industrial oils; engine lubricating oils; turbine oils; electrical insulating oils; lubricating greases; petrolatums and paraffin waxes; plant spray oils and petroleum sulfonates; bituminous materials; coal; industrial aromatics; and general testing methods.

It's Toronto in '57
ASLE-ASME
4th Lubrication Conference

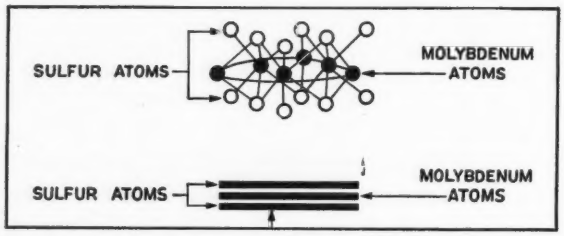
Effective lubrication of torsion suspension bushings of heavy duty trailers has been a maintenance problem with many truckers. The bushing at the left was removed still in good condition after 160,000 miles of service. This bushing was lubricated with a chassis grease containing Moly-Sulfide additive. The bushing at the right, lubricated with ordinary chassis grease, needed replacement after 35,000 miles of service.

How Moly-Sulfide additives EXTEND EFFECTIVE LUBRICATION

Why Moly-Sulfide additives are used in lubricants by trucking fleet operators, railroads, aircraft and automotive manufacturers, oil well drillers and steel mills.

Moly-Sulfide has six characteristics which make it an ideal lubricant additive wherever mechanical action wipes or shears off the hydrodynamic film.

1. Because of its affinity for metals, Moly-Sulfide readily forms a film on metal surfaces.
2. Moly-Sulfide has a low coefficient of friction.
3. It has a high factor of durability.
4. Moly-Sulfide has a thermal stability of −100°F. to +750°F.
5. It has a high chemical resistance to acids, alkalis and water.
6. It withstands high pressures, having a low shear strength and a high film strength.

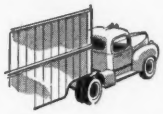


Above, structural diagram of the Moly-Sulfide molecule. Below is a functional illustration of the laminar structure. Each lamina is composed of a layer of molybdenum atoms with a layer of sulfur atoms on each side.

What is Moly-Sulfide and how does it function in lubrication?

Mined in Colorado as molybdenite, purified Moly-Sulfide is a lead-grey material. It has a laminar molecular structure, with the Moly atoms sandwiched between layers of sulfur. (See illustration.) The sulfur atoms have an affinity for metal and

bond readily to metal surfaces, giving the film a *low shear strength.* This affinity is caused by a strong intermolecular bond between sulfur and metal. The lubrication results from the easy slippage of sulfur-to-sulfur atoms. As an additive to lubricants, the *Moly-Sulfide will readily form a film and when a grease or oil film is wiped away or sheared off, the Moly-Sulfide film sustains lubrication until a petroleum film reforms.*



Truck and passenger car builders and operators are making wide use of Moly-Sulfide greases for difficult lubrication jobs.

Lubricants containing Moly-Sulfide additive have over 30 established uses in the automotive, aircraft, railroad, oil drilling and steel industries.

Since Abraham Lincoln's time, railroads have been faced with a serious, recurring, *expensive* problem: hotboxes. Right now more than 14 million journal bearings are carrying heavy loads at high speeds on American railroads. These railroads have to deal with an average of 183,000 hotboxes a year at a cost of some $90,000,000.

Initial field tests by at least three leading railroads have shown hotboxes can be reduced materially by the use of grease containing Moly-Sulfide. A way has been devised to apply greases containing Moly-Sulfide on the journals of railroad equipment. This application is supplemental to the oil waste system and as a result the Moly-Sulfide films that are formed sustain lubrication until the oil film is reestablished.

American automobile and truck manufacturers and their customers are now using lubricants containing Moly-Sulfide additive in at least 14 different applications. These include chassis points, ball joint suspensions, torsion suspension assemblies, fifth wheels, shackle bolts, king pins, valve stems, automatic window mechanisms, wind-shield wiper mechanisms, seat adjusters, drive shaft splines.

In aircraft, Moly-Sulfide is added to aircraft greases. In jet engines under exacting conditions of temperature and pressure it is used on turbine shaft, splines and gear reduction units.

In other industries, Moly-Sulfide is being used in lubrication jobs which formerly presented serious difficulties. A Florida cement plant is using gear compound containing Moly-Sulfide to lubricate rack gears and a Michigan manufacturer uses Moly-Sulfide as an additive to drawing compounds for drawing stainless steel hub caps. In New York a baker of crackers and cookies is using Moly-Sulfide grease for lubrication of oven chains which must operate at high temperatures. In Louisiana an oil well drilling contractor is using Moly-Sulfide additive in tool joint compounds. He reports that disjointing when drilling below 15,000 feet is no problem now: no galling, welding or stripped threads.

Aircraft manufacturers are using Moly-Sulfide greases on many types of ball and joint suspension lubrication.

Oil well drilling contractors are using Moly-Sulfide additives to tool joint compounds.

Lubrication engineers are offered information and help in evaluating the use of Moly-Sulfide as an additive to lubricants by the Climax Molybdenum Co.

Currently Moly-Sulfide is being investigated by many petroleum research laboratories and lubricant users. They are interested in studying, under practical working conditions, the ability of Moly-Sulfide to increase effective lubrication.

If insuring effective lubrication is a problem facing your company, Moly-Sulfide additives may be a solution. Climax Molybdenum Company is the principal source of this product. If you need authoritative information, please get in touch with us and we will be pleased to send you literature on Moly-Sulfide and the sources of supply for experimental lubricants containing Moly-Sulfide.

DEPARTMENT 38
CLIMAX MOLYBDENUM COMPANY
500 Fifth Avenue, New York 36, N. Y.

Please send me the following:

Literature
1. "Moly-Sulfide, Lubricant Additive" ☐
2. "Moly-Sulfide in Chassis Grease" ☐
3. "Moly-Sulfide Specification and Properties" ☐

List of Sources for
1. Railroad Greases ☐
2. Chassis Greases ☐

Sample — One-ounce tube of Moly-Sulfide ☐

Name .....

Position .....

Company .....

Address .....

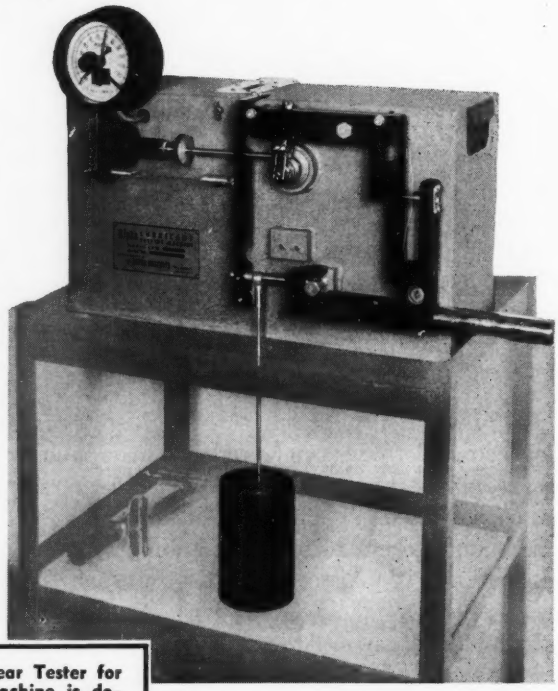
CLIMAX MOLYBDENUM

The Better The Test Equipment...
THE LOWER THE COST OF PRODUCTIVE RESEARCH

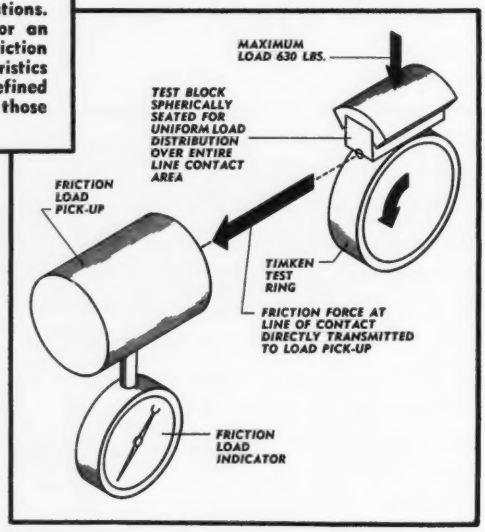
PRECISION TESTING IN THE LOW VELOCITY E. P. RANGE

Admittedly the greatest single handicap in boundary lubricant research has been the lack of tools in the form of accurate and reliable bench test equipment. The stark oversimplification of E.P. testing equipment contrasts sharply with the complexity of friction and wear phenomena. The Alpha Model LFW-1 is the result of a search for an "intermediate" between the oversimplified E.P. Bench Test and costly and time consuming full scale performance tests. Such intermediates, of which many are needed, cannot fail to sharply reduce the terrific waste of research expenditure and talent.

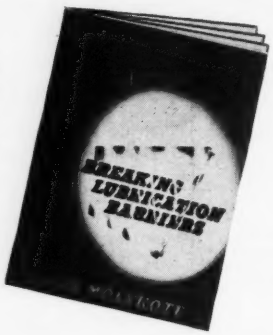
Since all E.P. lubricity ingredients function effectively only in a limited temperature range, E.P. Bench Tests must either measure frictional contact temperature or, pending the development of means to do so, simulate them. Sliding velocity is one important factor in this simulation. A large group of E.P. lubricity ingredients which are highly successful in industrial low velocity mechanisms completely fail to respond on most E.P. testers because excessive velocities and loads combine to produce frictional temperatures beyond the functional temperature range of the E.P. ingredient.



Alpha Model LFW-1 Lubricant-Friction-Wear Tester for sliding velocities below 43 feet per minute. Machine is designed for low velocity extreme bearing pressure applications. Developed by professional testing machine designers for an accuracy of better than 98% in load, velocity and friction measurements, results reflect the performance characteristics of a lubricant in a uniformly loaded and accurately defined friction area. The only variables from test to test are those intended by the operator.


MAXIMUM LOAD 630 LBS.
TEST BLOCK SPHERICALLY SEATED FOR UNIFORM LOAD DISTRIBUTION OVER ENTIRE LINE CONTACT AREA
FRICTION LOAD PICK-UP
TIMKEN TEST RING
FRICTION FORCE AT LINE OF CONTACT DIRECTLY TRANSMITTED TO LOAD PICK-UP
FRICTION LOAD INDICATOR

If you have a really important lubrication job to do involving extreme pressures or extreme temperatures, try MOLYKOTE Lubricants. Send today for complete application data and your copy of "Breaking Lubrication Barriers . . . with MOLYKOTE".



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The ALPHA MOLYKOTE Corporation

MAIN FACTORIES: 65 Harvard Avenue, Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

ASLE News Notebook

Compiled by
R. D. McCormick

Entertainment Announced for Annual Meeting Banquet

Members and guests and their wives will be entertained by Warney Ruhl and his eleven piece orchestra at the Annual Meeting Banquet, April 16, 1957 in Detroit, Michigan. "Miracles in Music" by the Ruhl orchestra will feature Patti Brown, vocalist; Vina at the piano and celesta; the Ruhltones, a vocal group; and the Happy Three, a vocal trio. Dancing will begin immediately after the dinner and presentation of awards.

During the dinner and cocktail reception, entertainment will be provided by a strolling group of three musicians. After dinner, in addition to the dance music, Jack Herbert, well-known comedian will serve as master of ceremonies to add to the evening's entertainment.

Tickets for the banquet will be available during registration hours at $8.50 per person. Cocktails will be served at the reception beginning at 6:30 P.M., Tuesday evening in the Book Casino, and dinner will be served at 7:00 P.M. in the Crystal Ballroom. Dancing will continue until midnight.

ASLE Members Author New Book

Dr. E. R. Booser, National President of ASLE, together with Dr. D. F. Wilcock, Eastern Area Representative and past chairman of the ASME Lubrication Division, have recently written the book "Bearing Design and Application" which has been published by McGraw-Hill Book Co. Both authors are employed by the General Electric Co. at Schenectady. Bearing design and application is considered from three aspects: the design of the bearing, including its geometry, general configuration, and tolerances; the materials from which the working parts of the bearing are constructed; and the lubricant employed. Rolling contact, slider bearings, bearing materials, and trouble shooting are included.

Detroit Members to Serve Visiting Members and Guests at Annual Meeting

Members of the Host Detroit Section will be identified with a circular badge inscribed with green lettering *"Ask Me — ASLE — Detroit, 1957"*. Each member of the section has volunteered to assist visiting delegates to the Annual Meeting by directing them to points of interest, or answering questions about the City and its features. Members and guests of ASLE attending the Annual Meeting are urged to direct all questions of direction and City accommodations to members of the Host Section. City maps will be available at the registration desk.

Mr. H. E. Kaye (left), past Chairman of the Syracuse Section, and Mr. R. Buyea, current Chairman, flank Dr. A. G. Cattaneo, Shell Development Co., who spoke before the February meeting of the Section.

Boston Section Awards Completion Certificates

Certificates of Completion were awarded to 106 students at the final session of the Lubrication Engineering Course sponsored by the Boston Section and held at the Massachusetts Institute of Technology on March 18.

C. R. Lewis, National Program Chairman, reports on plans for the 1957 meeting before the January Board meeting. Shown seated are: J. H. Fuller, W. Lasky, S. R. Calish, J. L. Finkelmann, D. W. Sawyer, R. D. McCormick, R. F. McKibben, W. H. Fowler, Jr., A. B. Wilder, J. D. Lykins, J. O. McLean, E. R. Booser, C. L. Willey, A. E. Cichelli, and M. E. Dougherty.

Advance Information!

4th Joint Lubrication Conference

Co-Sponsored by ASLE-ASME

Papers currently being considered by the reviewing committee—

"The Effect of Aircraft Gas Turbine Oils on Roller Bearing Fatigue Life"

"Extremely Thin Film Hydrodynamic Lubrication"

"A Solution for the Finite Journal Bearing & Its Application to Analysis and Design — III"

"A Theory of Cutting Tool Wear & Cutting Oil Action"

"Solid Film Lubricants at High Temperatures"

"Investigation of Factors Governing Rolling Contact Fatigue Life in the NACA Fatigue Rig"

"Wear of Cobalt-Base & Stainless Steel Materials in High-Purity Water"

"Influence of Lubricants on Gear Fatigue"

"A Study of Piston Ring Face & Side Wear Characteristics by the Radioactive Technique"

"A Study of the Effect of Wear Particles & Adhesive Wear at High Contact Pressures"

"Lubricity Studies Under Extreme-Temperature Conditions"

"The Role of Atmospheric Oxidation in High Speed Sliding Phenomena"

Watch *Lubrication Engineering* for further information on this important conference.

4th Joint Conference of the ASLE-ASME
October 7, 8, & 9, 1957

Royal York Hotel
Toronto, Ontario, Canada

Members of the NRLC and Industry met with Mr. Franz Pfeufer, Lubrication Engineer from Germany, to discuss problems dealing with the winter operation of diesel engines used for railway service. Shown in the photo are: J. C. Kleber, R. G. Kandlbinder, Herr Pfeufer, J. E. Rosnell, V. C. Barth, Mr. Simpson, and W. H. Day.

New Chairman Appointed

Mr. A. E. Baker, General Electric Company, has been appointed chairman of the Fluids for Metalworking Committee. The meeting of this committee has been scheduled for Monday, April 15 at 10:00 a.m. in Parlor K at the Sheraton-Cadillac Hotel during the Annual Meeting.

Most of the technical committees of the Society have scheduled meetings during the Annual Meeting. Meeting times and rooms will be posted on the Bulletin Board at the hotel.

Executive Committee members for 1956-57 include: J. L. Finkelmann, C. L. Willey, E. R. Booser, J. W. Hopkinson, J. W. Peterson, and J. O. McLean.

Baltimore Chapter Sponsors Practical Lubrication Course

A course in practical lubrication was sponsored by the Baltimore Section on March 20 at the Stafford Hotel, Baltimore, Maryland. Five technical sessions and a question and answer panel were featured during the one day course. Speakers included Mr. F. M. Beall, *"Principles of Lubrication"*; Mr. A. E. Cichelli, *"Application of Lubricants"*; Mr. J. P. Kellog, *"Handling of Lubricants Film"*; Mr. M. M. Gurgo, *"Properties of Lubricants"*; Mr. C. R. Hand, *"Practical Plant Lubrication"*; and the question and answer panel composed of the foregoing speakers.

Connecticut Engineering Course Draws 78

Students enrolled in the Lubrication Engineering Course sponsored by the Connecticut Section were guests of the Connecticut Section on March 20 and received Certificates of Completion. The final meeting of the course was combined with a plant visit (beginning at 3:00 in the afternoon) of the Scoville Manufacturing Company at Waterbury, Connecticut. The tour was followed with a social hour and dinner, and the technical session of the evening treated "Roll Oil" in panel discussion. Almost 75% of the students enrolled for the course were nonmembers of the Society and represented a high potential membership for the Section. *Section officers interested in planning lubrication engineering courses for their Section should contact their area representative or Regional Vice-President for details.*

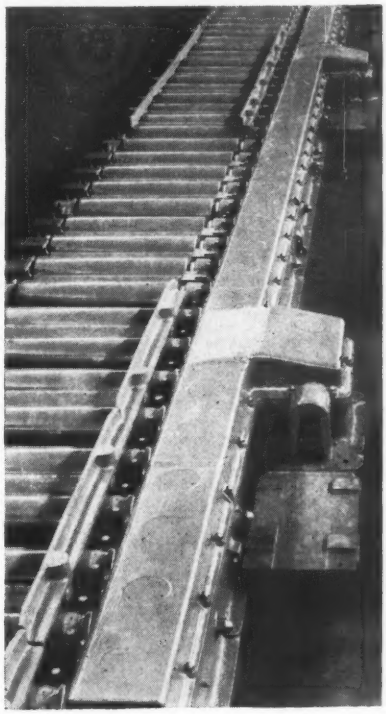
Program Committee members discuss last-minute program details for the Annual Meeting at the January Board meeting in Detroit. S. B. Twiss, Chrysler Corp.; C. R. Lewis, Standard Oil Co. (Ind.); J. A. Brady, Penn-Petroleum Corp., and D. W. Sawyer, Aluminum Co. of America, are shown seated. H. S. McCulloch, Jr., Shell Oil Co., program chairman of the 1958 meeting, was not present for the photograph.

THE BROOKS OIL CO.

Lube-Engineering News

A REPORT ON THE DIFFICULT LUBRICATING PROBLEMS OF INDUSTRY

93% SAVING IN MILL TABLE LUBRICATION COSTS REPORTED BY LEADING STEEL PRODUCER



A leading steel producer recently went through a series of corrective measures to improve lubrication of mill tables. They went from circulating oil system to pressure grease system and finally to automatic spray system.

In the spray system, they used Brooks Klingfast and reported a savings of 93% in lubricant cost. They do not attribute the saving to the change in equipment, as various lubricants were tested. Klingfast offered the greatest reduction in lubricant cost for the application.

Records indicate a 35% decrease in man hours spent on this lubrication job, and 65% less maintenance delays due to improved lubrication. Klingfast has proved itself against adverse conditions of mill scale, water and high temperatures. Savings in maintenance costs were coupled with increased production.

For full information, write for Engineering Letter 73LE.

NEW COLOR FILM AVAILABLE TO LUBE-ENGINEERING GROUPS

This new 30 minute 16 mm motion picture, in full color, with sound, shows a number of tough lubrication jobs. It pictures and describes the research, manufacturing and quality control methods that enable Brooks lubricants to "stand up" under severest service.

It's available to any supervisory or engineering group interested in lubrication problems. No charge, of course — we're glad to have you see it. Just call or write any of our offices and tell them you want to borrow "The Brooks Oil Story."

CIRCULATING OIL SYSTEMS REQUIRE LUBRICANTS THAT WITHSTAND SEVEREST CONDITIONS

Dust, dirt, water and metallic contamination present extremely difficult problems for circulating oil system lubricants — in steel mills, forging and press shops, cement plants and many other industries. Lubricating compounds must withstand constant contact with contamination, readily dissipate such foreign matter and maintain quality for continued service.

Brooks Leadolene and Klingfast are compounded to meet such severe conditions. These products have served industry for more than a quarter of a century and have broken many records. Companies in the United States and Canada have obtained 5, 10, 15 and 20 years of continued service from these lubricants. For complete facts, see your Brooks representative or write for Engineering Letter 86LE.

THE BROOKS OIL CO. 81st YEAR 1876 1957

THE BROOKS OIL COMPANY

EXECUTIVE OFFICES AND PLANT—CLEVELAND, OHIO
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American Potash & Chemical Corporation, through its subsidiary, American Lithium Chemicals, Inc., is a basic supplier of Lithium Hydroxide Monohydrate—vital to high quality multi-purpose greases.

LITHIUM BASE GREASE

one grease...in place of many ...for industrial lubrication needs!

Multi-Purpose Grease provides these outstanding properties...

- Water resistance
- High temperature bearing performance
- Low temperature pumpability
- Greater chemical and mechanical stability
- Stepped-up oxidation resistance
- Rust and corrosion prevention

"ONE-TYPE" grease for every purpose can now prevent the misapplication of lubricants in equipment, provide economies in storekeeping and manpower by eliminating special-purpose grease products. Lithium-base, multi-purpose lubricants simplify maintenance and minimize dispensing equipment required in industrial, farm and mobile equipment. A vital ingredient in these tough and versatile greases is Lithium Hydroxide Monohydrate, which imparts the ability to withstand wide ranges in temperature, water contamination and variable loads and speeds. For everything—from electric motors to locomotives—lithium-base greases will do the job and do it better.

Write for informational bulletin containing technical data on Trona* Lithium Hydroxide Monohydrate.

*TRADEMARK AP&CC

TRONA

American Potash & Chemical Corporation

Producers of: BORAX • POTASH • SODA ASH • SALT CAKE • LITHIUM • BROMINE • CHLORATES • PERCHLORATES • MANGANESE DIOXIDE • *and a diversified line of specialized agricultural and refrigerant chemicals*

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Annual Meeting (Detroit).....J. A. Brady, Penn-Petroleum Corp.
Annual Meeting Sites.....J. D. Lykins, Wheeling Steel Corp.
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Journal Bearing Research.....E. M. Kipp, Aluminum Co. of America
Lubrication Conference.....E. E. Bisson, National Advisory Committee for Aeronautics
Membership & Admission.....B. T. Harding, Midwest Oil Co.
Nominations.....J. W. Hopkinson, Penn-Petroleum Corp.
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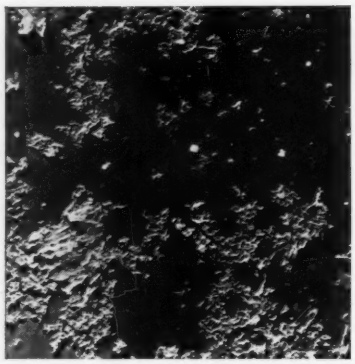

1μ

Micrograph showing soap structure of lithium base lubricating grease made from 12-hydroxy stearic acid. Courtesy of Sinclair Research Laboratories, Inc.

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Lube Lines

by A. F. Brewer*

GASEOUS LUBRICATION

Industry today must be equally as concerned with the unconventional as with the conventional. Developments in machine design over the past twenty years or so have proved that the fantastic of yesterday can well become the practical actuality of tomorrow. We have only to review the advancements in operating speeds, temperatures, and pressures to realize that, given adequate lubrication, virtually any mechanical objective is attainable.

Along with these brain children of the designing engineers have come the products of chemistry and the petroleum industry. As yet, however, as far as lubricants are concerned, Management still has only the fluid, semi-solid, and solid products to choose from. Tomorrow, on the other hand, they may well be able to utilize gaseous lubricants, if research continues to be as active and promising as presently indicated.

The idea is not entirely new; the theory has been known for more than half a century. In effect, this possibility of using a gaseous material as a lubricant between solid metallic surfaces in sliding or rolling contact with respect to one another, dates back to the classic research of Albert Kingsbury. He demonstrated that under certain conditions of speed and load, the fundamental principles of the hydrodynamic theory prevails—to the end that the center of a rotating shaft approaches the hypothetical center of the bearing, with complete separation of the opposing surfaces. Evidence of this, and the fact that a state of clearance around the entire shaft existed, was demonstrated by Mr. Kingsbury by the breaking of an electrical contact between the shaft and bearing metal to prove that a layer of air in the resultant clearance space functioned as the lubricant. More recently Professor Dudley Fuller at Columbia University has projected this idea to the extent that there is practicable evidence of its applicability to certain phases of machine design and operation. His research has been reported before the ASLE in considerable detail. Interest to date is centered upon application to three types of machines or service, i.e.,

1. Where contamination must be avoided as, for example, in closed-cycle gas turbines.

2. For high-temperature service where operation must be carried on at temperatures around 1000°F.

3. For high-speed conditions where shaft-rotational velocities may reach 100,000 rpm. At present, perhaps the majority of applications are in this field.

Table I
Advantages Claimed for Air Lubrication

1. Very low frictional resistance; in fact, virtually negligible.
2. Possibility of contamination is reduced to a minimum.
3. Maximum cleanliness.
4. Negligible fire hazard.
5. Adaptable to considerable bearing pressure where compressed air is available.
6. Adaptable to very high temperatures because air increases in viscosity with increase in temperature.
7. Adaptable to very high speed where the extremely low viscosity, as compared with lubricating oil, indicates great promise due to low friction loss and less heat.

Of course there can be some objections to air lubrication. Unless it is used under absolutely dust-free conditions, wear or metallic abrasion could develop. Wear also could be expected to occur when starting up a machine, due to actual metal-to-metal contact. This could be obviated, however, to some extent by employing an auxiliary air pump at the time of starting to raise the shaft and reduce the dead weight contact on the bearing over the area of maximum pressure, although this might introduce mechanical complications. This same idea is used to good advantage with oil lubrication on such heavy duty machinery as paper calenders, where the weight of the stack of rolls upon the bottom roll bearing is relieved by pumping oil into the clearance space of the latter.

Fortunately, other gasses have been found to have more actual boundary lubricating value especially where steel-to-steel is the metallic combination. The research of S. F. Murray, R. L. Johnson and M. A. Swikert at the Lewis Flight Propulsion Laboratory of the NACA suggests halogenated gases as possible lubricants. They have further suggested that the extent to which effective lubrication can be attained with any such gas will be dependent upon the metal combinations involved. Their work has included Monel metals, stainless steels, silver, and Inconel. Data currently indicates best results with hardened tool steels.

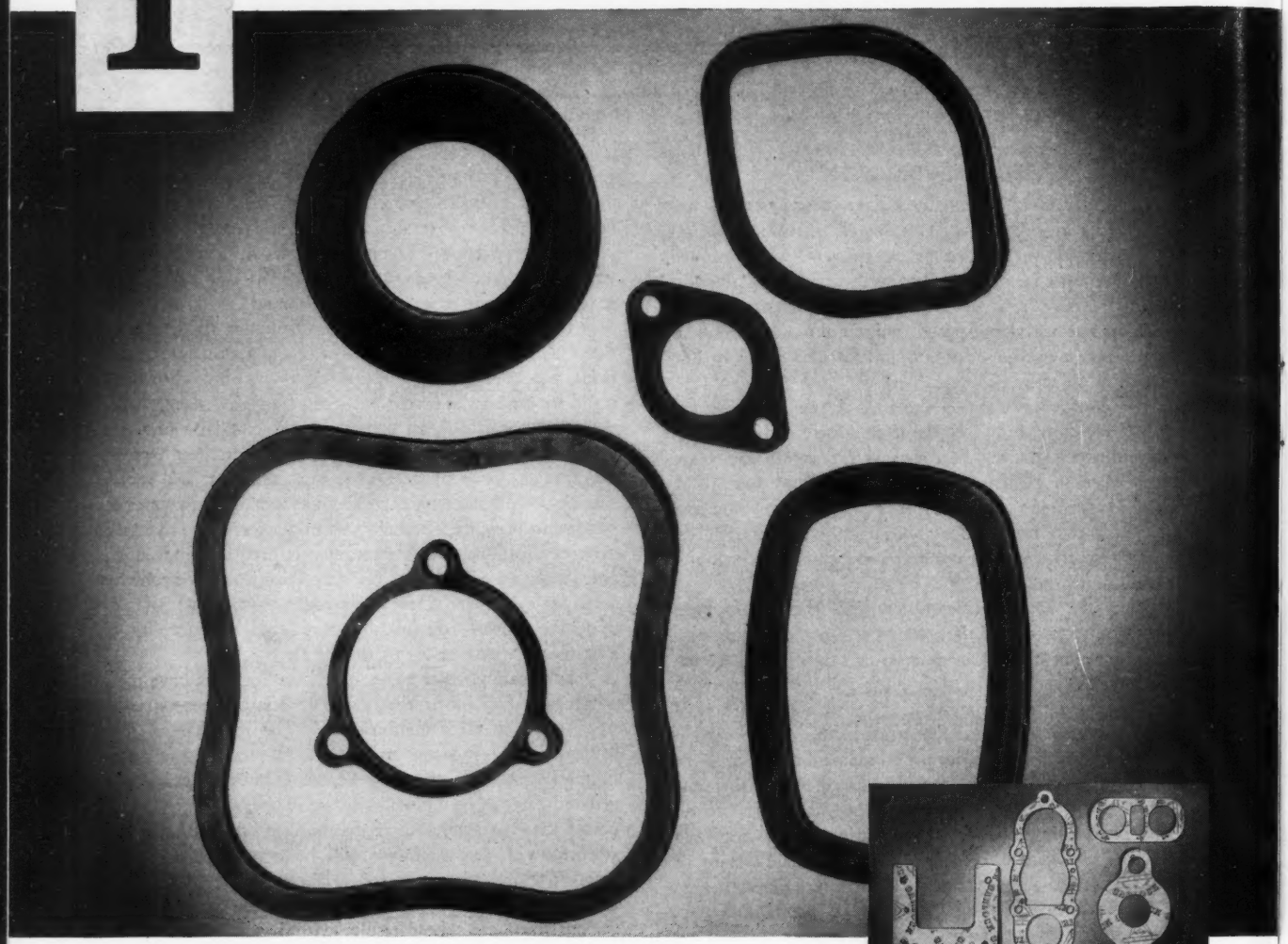
In this work, dichlorodifluoromethane was given especial attention, to determine its usefulness as a boundary lubricant under high-temperature conditions beyond the range of acceptability for petroleum-base lubricants. Hardness of the steel was found to be important in this research; the most satisfactory results were noted when the test specimens were of about the same relative hardness and the same degree of surface finish. The theory advanced to explain the lubricating value of such gases is that a chemical reaction occurs with the steel surfaces to form an iron chloride surface film in much the same way as an EP additive functions in a petroleum-base lubricant.

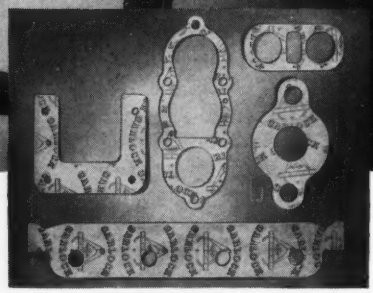
With any gaseous lubricant it is important to remember that moisture, condensation of gas, and contamination are possibilities which the designing engineer must consider most seriously if he is to develop a mechanism for practical application which can be effectually lubricated in this manner. With the extent to which Management today is promoting research, it is not too extravagant to predict that gaseous lubrication will become a factor and an actuality in the not-too-distant future when high-temperature and high-speed service is involved and it is economically practicable to design a well-sealed unit.

*Consultant, and Author of *Basic Lubrication Practice.*

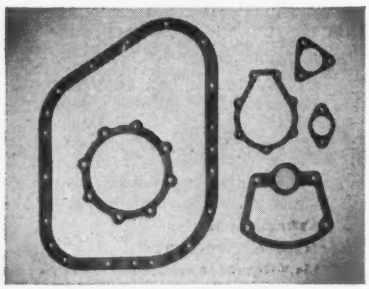
★ ASLE-ASME 4th Lubrication Conference, October 7-8-9, Toronto ★

1 GASKET OR 1,000,000





Rubber Gaskets



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Cam & Tappet Test for Lubricants I—Anti-Scuff Evaluation

E. H. Loeser, D. M. Teague, P. J. Willson & S. B. Twiss
Chrysler Corporation
Engrg. Div., Chemical Research
Box 1118
Detroit 31, Michigan

A description is given of a bench-type lubricant tester for the study of metal scuff under combined sliding and rolling contact, with cyclic variation of load. The scuffing of a hardenable iron tappet riding on a cast iron cam is delayed by a run-in at moderate load or by the use of an oil containing a small percentage of the additive, zinc dialkyl dithiophosphate. A short run-in with the additive oil protects the parts against scuff, even when a non-additive oil is used subsequently. This study points up anti-welding film formation and controlled wear as important mechanisms in scuff prevention. This wear increases the contact area and thereby decreases the unit loading on the mating parts.

INTRODUCTION

The work reported here is a part of a larger study undertaken a few years ago to investigate the effect of lubricants and cam and tappet materials on scuff and wear of these parts in engine valve trains. At that time, film-strength additives were introduced into engine oils to protect cams and tappets from scuff. In the case of certain additives, with chill cast tappets, a fatigue-type attack occurred on the tappet face. This led to roughened tappets which, in turn, produced excessive wear of cam lobes. The change from chill cast to hardenable iron tappets eliminated this problem, but methods were still sought to improve scuff resistance by improved run-in or the use of film-strength or extreme-pressure additives.

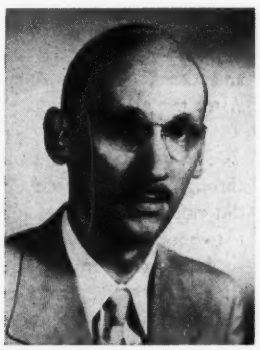
Scuffing is characterized by the formation of deep grooves, rapid surface roughening, and welding and tearing away of the surface metal. The mating parts rapidly lose their ability to function because of the resultant "catastrophic wear."

Most of the previous studies devoted to the failures of cams and tappets were based on dynamometer and road tests. These data are of limited value, since the number of variables which remained uncontrolled were very large. A road test program adequate for a statistical evaluation of the various factors which influence the failure of cams and tappets would be prohibitively expensive. Our approach to the problem is through the use of a bench tester where design, metallurgy, and operating conditions can be controlled more easily. The object of this paper is to report some of our results of an investigation in which the lubricant is the main variable. This evaluation required a fast and reproducible bench test in which the test pieces are subjected to cyclic variation in pressure, and in which the contact of mating parts is both sliding and rolling. The lubricant tester developed for this study is based on four tappets riding on a motored camshaft. The type of contact and surface stresses are similar to those found in many extreme-pressure applications. The motion is characteristic of extreme-pressure lubricated mechanisms such as hypoid gear and cam-tappet assemblies. Among the earlier bench type testers is a 500 cc. twin cylinder air cooled engine which was used to evaluate the wear of tappet materials for motorcycle engines.[1] J. R. Hughes and R. Tourret[2] have used a simple cam and tappet type of rig for the evaluation of gear lubricants. Their results showed reasonable correlation with results obtained on a high-speed gear assembly. A more recent tappet test machine has been used to investigate tappet materials with regard to scuffing tendency, wear and sensitivity to type of lubricant.[3]

The effects of the test piece geometry and material were evaluated during the development of our test apparatus. By careful selection of test pieces and operating conditions, random effects were minimized in order that the relation between lubricant and scuff conditions could be

This paper was presented at the ASLE 11th Annual Meeting, Pittsburgh, April 4, 1956.

E. H. Loeser



D. M. Teague

S. B. Twiss

P. J. Willson

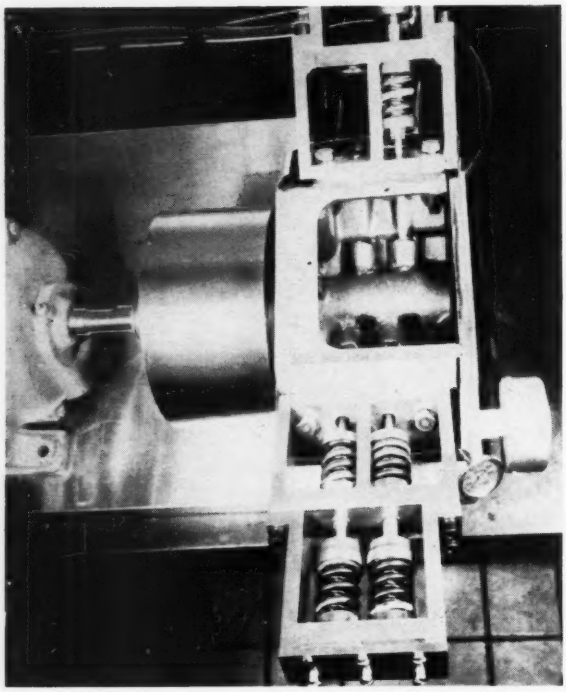


Figure 1. Cam & Tappet Lubricant Tester; top view showing pushrod load assembly.

studied. The design of the apparatus and test procedures were directed toward control of the significant conditions so that individual variables could be isolated and studied. This is extremely difficult in an engine or gear assembly. In the preliminary runs of the tester, the oils were selected on the basis of a qualitative knowledge of their ability to prevent scuff in the automotive engine. Thus, a rough picture was obtained of the correlation between tester and engine results.

APPARATUS & PROCEDURES

Apparatus

The test apparatus (Figure 1) consists of a section of the block of a V-eight engine enclosed in a steel box. This section provides the bearing support for the first quarter (four cams) of a camshaft and tappet guides for four tappets. A combination bearing and oil seal is used to prevent oil leakage around the end of the camshaft which extends through a hole in the box. A heavy flywheel interposed between the shaft and the motor coupling smooths out the rotation of the camshaft as the load passes over the cam lobes. A 2 hp. electric motor drives the camshaft at 1750 rpm.

The oil required to immerse the cams (1.9 quarts) is held at a predetermined temperature ($\pm 5°$F.) by automatic regulation of water cooling coils and electric heaters.

Superstructures mounted securely on the sides of the block support the pushrods and springs in positions axial with the tappet guides. The spring load is applied to a pushrod which transmits it to the tappet by direct, mechanical (non-hydraulic) contact. The load is varied by the selection of proper combinations of springs of different rates; equal loading is obtained on each of the four tappets. All springs were calibrated on a compression tester. The load which the tappets exerted on the cam noses ranged from 200 lbs. at the start of a run to about 950 lbs. at the end of the run. The springs were designed so that the load on the flat of the cam was always about 1/7 of that on the nose of the cam. An inertia weight of 1.4 lbs. on the pushrod was maintained throughout the runs.

Test Specimens

The test pieces were of standard camshafts and spherical-faced mechanical tappets used in V-8 automotive engines. These test pieces have the advantages of being designed for extreme-pressure operation, are reproducible within very close tolerances, readily available, and moderate in cost. The camshaft was of a high-strength cast iron (Chrysler MS-891), cut off behind the second bearing so that the first four cams and associated bearings remained for test. The finished cams had been hardened to a minimum of 49 Rockwell C. The roughness of the cam-rubbing surface was 10 microinches rms. The tappets were of high-strength hardenable cast iron (Chrysler MS-3288); the hardness of the finished pieces was about 61 Rockwell C. The microstructure of the tappet faces was controlled to fairly narrow specification limits by microscopic selection. These tappet faces had been finished to 4 microinches rms. before they were phosphate treated.

Since this paper is concerned with the scuffing of surfaces under combined sliding and rolling contact, rotation of tappets was assured by the selection of test pieces for correct geometry. Tappet rotation is produced by the use of a cam which is tapered to a slightly larger diameter at one side of the rubbing surface. The tappet has a spherical contact face with a radius of 25 inches. Rotation is produced because the tapered cam contacts the tappet slightly off center. If the spherical tappet face is substantially tipped, it can become parallel to the cam and no rotation will occur. This condition was avoided by making certain that the tappet contact face eccentricity was less than 0.0005″ from one edge to the other. The average of the cam tapers was 7.5 ± 0.5 minutes.

Two refined petroleum oils (A and B) of SAE 10 viscosity were used as base stocks for blending with additive concentrates. An SAE 30 oil (C) closely resembled Oil A except for viscosity. Three additive concentrates were used. X is a commercial detergent additive containing calcium sulfonate, calcium phenate, and barium phenate; Y is an extreme-pressure additive containing sulfur, chlorine, and phosphorus; and Z is a film-strength additive containing zinc dialkyl dithiophosphate.

Operation Procedures

Sufficient oil (1.9 quarts) was placed in the clean apparatus to immerse the camshaft, the heaters turned on, and the unloaded camshaft motored to provide stirring. After the oil temperature of 220°F. was attained, the motor was shut off and the tappets were installed using the 220 lb. spring load for the run-in. The tappets were observed through the Lucite cover on the tester; any tappet which did not rotate at the start of a run was replaced. After a twenty-one hour run-in, the load was increased in 100 lb. increments until failure occurred; the running time for each increment was three hours. Successive sets of calibrated springs with increasing stiffness were used, always set to the same compression length for reproducible loading. The tappets were inspected after each increment. Scuff

failure was accompanied by excessive noise, smoking of the oil, or violent and erratic rotation of the tappet. Figure 2 shows the appearance of scuffed and of worn but unscuffed cams and tappets. The failed tappet was removed and the test of the remaining positions was continued to failure or until the upper load limit was reached. The anti-scuff rating of the oil is based on the time (and load) to failure.

RESULTS

Reproducibility of Tester

The bar graph of Figure 3 shows the scuff results obtained for the sixteen test pieces used in a series of four runs in non-additive Oil A. Positions 2 and 4 of the tester fail with good repeatability, but under less severe conditions than positions 1 and 3. This is chiefly due to the pushrods in positions 2 and 4 being at a slight angle to the axis of the tappet guides. Since positions 2 and 4 appear to be more susceptible to scuff, they were used to evaluate the anti-scuff properties of the oil; the other two positions were used to evaluate the wear properties.

Effect of Oil Viscosity

Test pieces run at 220°F. in non-additive oils of SAE 10 and SAE 30 grade failed at about the some load conditions. Over this range, oil viscosity had no effect on scuff.

Effect of Run-In With Non-Additive Oils

Figure 4 shows that scuff failure occurred very rapidly in either of the non-additive oils (A or B) under the conditions of high starting load (410 lbs.). A twenty-one hour run-in at 220 lbs. load in the same oils delayed scuff

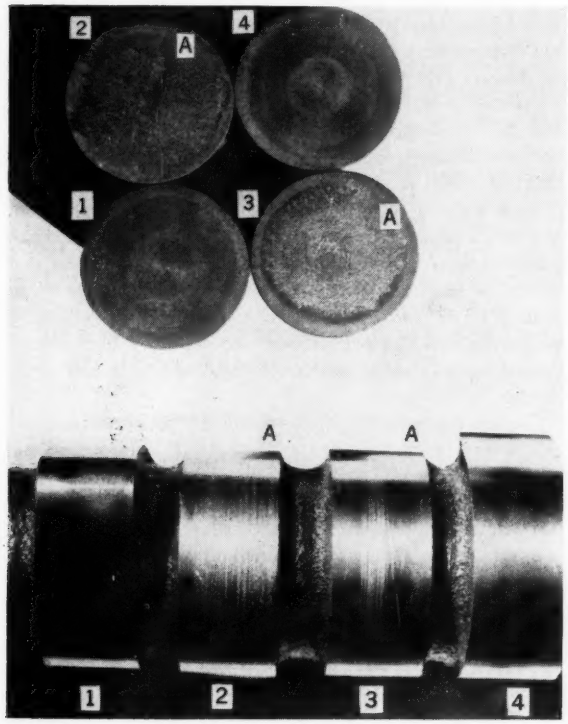


Figure 2. Scuffing failure of tappets (above) and mating cams (below); letter A marks scuffed pieces, others are worn but not scuffed.

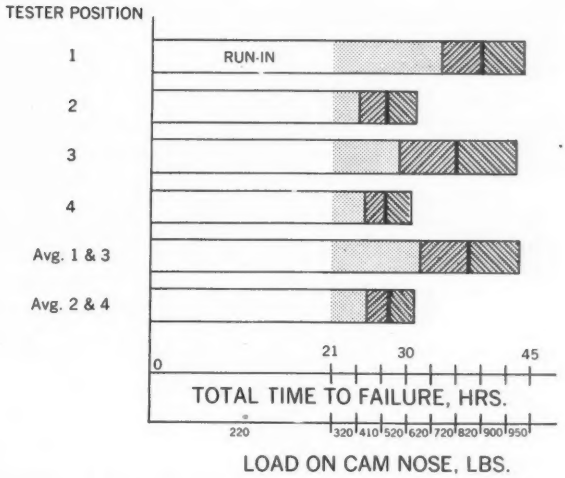


Figure 3. Reproducibility of scuff failures on the Lubricant Tester (Oil A).

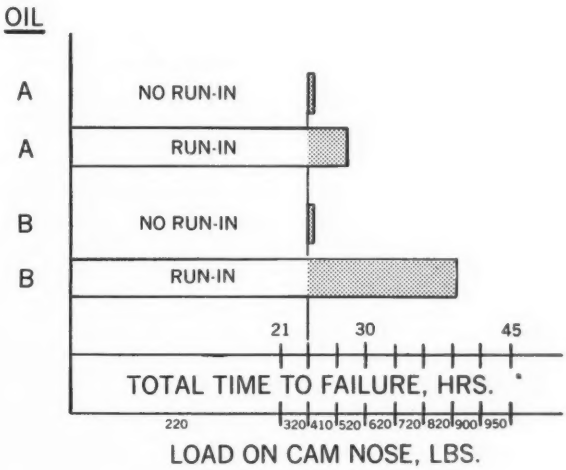


Figure 4. Effects of run-in and of base oil on scuff failure of Positions 2 and 4.

appreciably. The run-in with one non-additive oil (B) was more effective than with Oil A.

Effect of Run-In With Additive Oils

A second procedure involved a shorter run-in and a higher starting load. The test pieces were run at 410 lbs. load for one hour in an additive-containing oil. This oil was then drained and thoroughly flushed from the tester with kerosene. After the tester was cleaned, the test was completed in 100-lb., 3-hour increments using a non-additive oil.

Since a small quantity of an additive or impurity in the oil may have a marked effect on the test results, the apparatus was flushed three times with kereosene between oil changes.

Figure 5 shows that a one-hour run-in using various additives prevented early scuff failure in spite of high starting loads. The amount of protection appears to depend upon the type of additive and the quantity of additive used. The effect of incomplete removal of small amounts of additive oil from the tester is illustrated by the comparison of bars 4 and 5 of Figure 5. It should be noted that

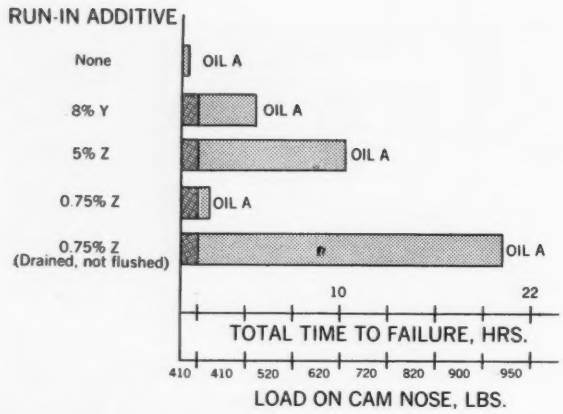


Figure 5. Effect of run-in additives on scuff prevention of Positions 2 and 4.

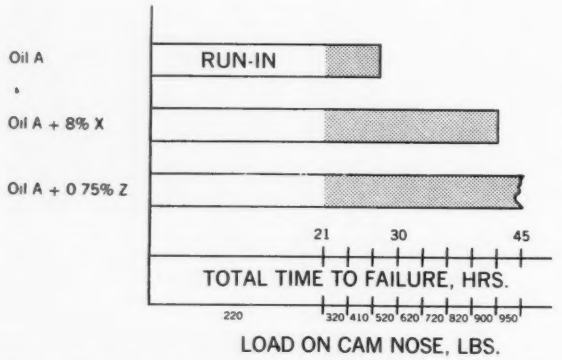


Figure 6. Effect of additive type on scuff failure of Positions 2 and 4.

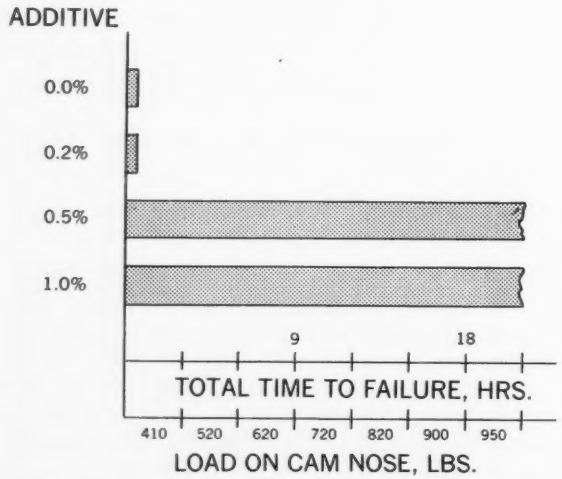


Figure 7. Effect of additive concentration (zinc dialkyl dithiophosphate) on scuff failure of Positions 2 and 4.

the protection against scuff provided by the one-hour run-in with the additive oils (bars 2, 3 and 4 of Figure 5) was retained when the additive oil was thoroughly removed from the tester and the run-in continued with a non-additive oil.

Effect of Oil Additives on Scuff

The bars of Figure 6 show that scuffing of the test pieces is affected by the type of additive in the oil. The detergent additive of the sulfonate-phenate type showed some protection, while the zinc dialkyl dithiophosphate protected up to the maximum load of the tester. The fact that the additive oils were used during the entire run, rather than only during a short run-in as in the earlier series of runs, accounts for the high loads sustained without failure.

The comparatively small difference between the results for the various oils may be due to the mild test conditions, which included a 21-hour run-in at 220 lbs. load.

Figure 7 shows the results for a base oil containing various amounts of zinc dialkyl dithiophosphate; 0.0% and 0.2% gave no protection against scuff, while 0.5% gave very good protection. The anti-scuff effect of the additive is more apparent in this series of runs involving severe operating conditions than in the earlier series (Figure 6). This third and most severe of the test procedures used a high starting load (410 lbs.) and no run-in. The load was increased in 100 lb. increments every three hours.

DISCUSSION

The maximum normal stress exerted by the spherical face tappet on the cam at various spring loads was estimated from a stress calculation given by Turkish.[4] Test pieces subjected to an initial 150,000 psi Hertz stress (410 lb. spring load) scuffed within twenty minutes in either of the two non-additive oils. On the other hand, test pieces run at an initial 130,000 psi Hertz stress (220 lb. spring load) did not scuff in any of the experiments. The results indicate that with this test apparatus and materials, scuff does not occur at 130,000 psi initial unit load, but does occur at 150,000 psi initial load in a non-additive oil.

After a 21-hour run-in, the cam and tappet were able to resist distinctly greater spring loads in Oil A. For Oil B, the beneficial effect is still larger; after run-in, failure did not occur until a spring load of 900 lbs. was reached. The increase in Hertz unit stress, however, is by no means proportional to this increase in spring load from 220 lbs. to 900 lbs., as will be indicated in subsequent calculations.

Oxidation stability tests indicated that Oil B is less stable than Oil A. The oxidation products formed in Oil B during the run-in may account for the better anti-scuff properties of Oil B. Measurements made on unscuffed test pieces run in these two oils indicated that the wear was about the same in each oil. Thus, it appears that, although mating of the surfaces occurred, the difference in anti-scuff properties was due primarily to the boundary film properties of the oxidation products formed in Oil B during the run-in.

Test pieces failed almost immediately in non-additive oils when the more severe test procedure of no run-in and high starting load (410 lbs.) was used. Test pieces, subjected to the same severe conditions, however, were able to withstand these initial Hertz stresses of 150,000 psi without failure if the oil contained a small quantity (about 0.5%) of zinc dialkyl dithiophosphate. This additive and a conventional sulfur-chlorine-phosphorus extreme-pressure additive appeared to cause changes during a one-hour run-in at 410 lbs. which permitted the test pieces to resist scuff when the run was continued in a non-additive oil.

The ability of sliding metal surfaces to withstand greater loads in an additive oil without scuffing is usually due to the formation of an anti-welding film on the metal surfaces. The formation of an anti-welding film by the

sulfur-chlorine-phosphorus extreme-pressure additive can be demonstrated by a variety of tests: Falex, 4-ball, and hypoid gear assemblies. Interestingly, although zinc dialkyl dithiophosphate addition shows a beneficial anti-scuff effect for cams and tappets, it has no significant extreme-pressure qualities, according to the Falex test. It has been called a film-strength additive, but the mechanism is not clear.

No attempt was made to determine the maximum initial load at which the various additives would prevent scuff. Although relatively high spring loads were attained during the later stages of some tests, the increase in Hertz contact stress was not proportional, since the contact area is increased by the wear and mating of the contact surface as the test progresses. The value of this mating process is indicated by the beneficial effect of run-in. Figure 4 shows that a simple run-in with a non-additive oil enables the contact surface to withstand higher spring loads without scuff. Moreover, the use of an additive in the oil during a very short run-in (Figure 5) permitted higher subsequent loads with non-additive oil. This latter effect is not due to traces of additive oil, since the tester was thoroughly cleaned before the non-additive oil was added.

A logical explanation for the beneficial effect of this run-in is apparent from careful measurements of the cam and tappet mated surface. Profile measurements made on the unscuffed test pieces after extended running with additive or non-additive oils showed that the cam surface wear approximated the contour of the tappet face. Test pieces run with additive oils showed greater wear of the cam surface than found in non-additive oils. The chemically-active additive aided in the removal of metal at the contact surfaces of the test pieces, resulting in a geometric mating of the surfaces as shown in Figure 8. Figure 8 is a proficorder tracing of mating cam nose and tappet surfaces after running, but before scuffing has occurred.

It is apparent from the mating contours that much greater length and, hence, area of contact is present in a worn cam than was present in the unworn surfaces at the start of the run.

Assuming that there is contact of spherical tappets on flat cam over an increased width of the cam at the nose (Figure 8), calculations indicate that the Hertz loading is considerably less than it would have been had no mating occurred. (To simplify the calculation, the slightly curved contact of these mated surfaces was considered equivalent to a flat-faced tappet contact on an equivalent width of cam.) For example, after tester operation with a non-additive oil for twelve hours at spring loads which ranged from 140 to 220 lbs., the actual Hertz stress was 99,000 psi based on the observed mating contact area. By contrast, the initial stress at 220 lb. load on an unworn cam and tappet would have been 130,000 psi. These spring loads are similar to those used in present automotive valve trains.

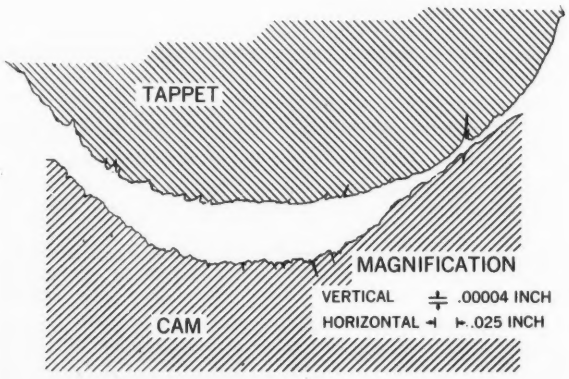


Figure 8. Mating of worn cam and tappet surfaces, from proficorder tracings.

In our accelerated test for the evaluation of the anti-scuff properties of oils, the spring load was increased from 220 lbs. until a maximum spring load of 950 lbs. was attained. The calculated Hertz loads at the maximum spring load, based on observed mating contact areas, was 151,000 psi for cams and tappets run in a non-additive oil, and 145,000 psi for those run in an oil containing 0.5% zinc dialkyl dithiophosphate. More wear and better mating of contact surfaces were obtained with this additive. By contrast, the initial stress at 950 lb. load on an unworn cam and tappet would have been 210,000 psi.

SUMMARY

The incidence of scuff failures in the automotive valve trains is small. Failure occurs most frequently during the initial operation of the engine. An effective anti-scuff oil must give the added protection required to survive this initial high stress period. The additive, zinc dialkyl dithiophosphate, appears to supply this protection through both its anti-welding and wear acceleration properties. The increased wear provides lower stresses because of the larger contact areas produced. It may be desirable under extreme load conditions to use additives subsequent to the run-in, although this will lead to slightly increased wear as will be shown in the second paper of this series.

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ACKNOWLEDGEMENTS. We wish to express our appreciation to A. Thomson, of Physics Research, for profilometer and proficorder measurements; to A. Tache, of the Metallurgical Laboratories, for tappet structure inspection; and to D. Kinker, of the Engine Laboratories, for helpful discussion.

SUMMARY OF REVIEWERS COMMENTS

In the past three or four years at least ten papers have been devoted to failures of cams and tappets by surface distress. These papers have shown that (a) metallurgy, (b) mechanical design of the valve train, (c) operating conditions, and (d) lubricant viscosity and additive content all affect performance. Wear, scuffing, and pitting comprise the three modes of failure.

"The authors' selection of materials and operating conditions somewhat limits their findings; in particular, it has already been established that hardenable cast iron tappets are relatively immune to surface distress; that is, they may be expected to show little response to lubricant additive content.

"Reproducibility of tappet failures has been generally acknowledged to be poor. Within one engine the variations have been so great that results have frequently been expressed as 'per cent of lifters scored', pitted, etc. Figure 4 purports to show that base oil B offers more load-carrying ability than A: 39 hours test duration vs. 28. But their Figure 3 reveals a spread of test results

from 24 to 45 hours encountered in duplicate testing. It can only be assumed that the data presented represent single runs; but if tests were replicated, this should be indicated in the paper. The implication in Figure 6 that sulfonate-phenate additives afford anti-scuff protection is similarly questionable.

"The efficiency of zinc dithiophosphates in preventing scuffing has been demonstrated by several authors. Comparison with these results would enhance the value of the paper.

"Increased scuff resistance following break-in with dithiophosphate additive oil is attributed to geometric mating of surfaces as a result of removal of 'high points' on the surface. This is somewhat in accordance with Beeck *et al* (*Proceedings of the Royal Society of London, Vol. A 177*, December 1940, pp. 90, 103) who called phosphorous a 'chemical polishing' agent. However, such mechanisms as anti-flux action from the sulfur or phosphorous, or the formation of a low-shear strength 'EP film' on the metal surfaces should be given more consideration. As a matter of fact, the interpretation given to the proficorder tracings (Figure 8) is difficult to accept."

COMMENTARY

G. H. ROBINSON, GENERAL MOTORS CORP.

The lubricant tester used in these investigations appears to be basically similar to the tappet test machine developed in the Metallurgical Engineering Department of the General Motors Research Staff. The original model of this test machine was described in a paper presented before the Society of Automotive Engineers about a year ago.[8] The present version of the tappet test machine, shown in Figure 1, employs as the cam sample a section of a production camshaft similar to that used in the Chrysler machine.

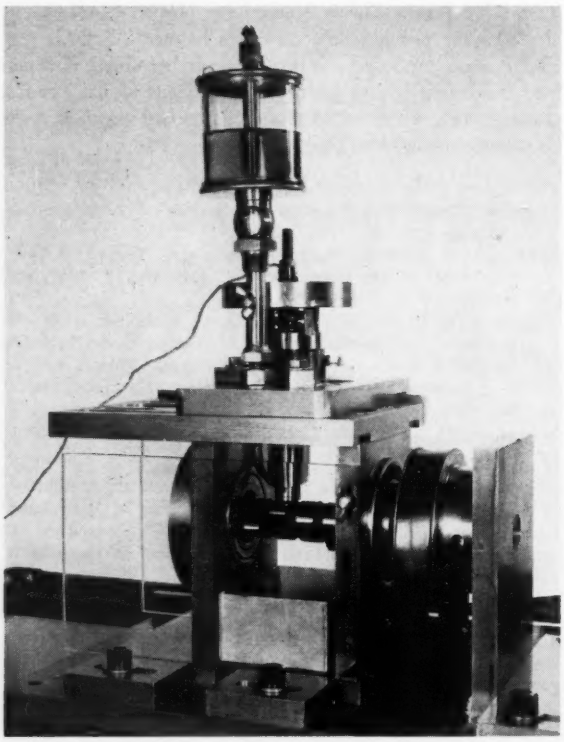

Figure 1. General Motors Research Staff Tappet Test Machine.

The tappet rides in a guide attached to a loading head which can be moved to position the tappet over the cam. This design of machine permits controlled variation of tappet offset and inclination, which does not appear to be possible with the authors' lubricant tester. Our general philosophy of test procedure is quite similar to that described in these papers, although operating conditions in the General Motors Research test differ considerably from those of the present authors. Results which we have obtained are, for the most part, in agreement with the authors' observations.

The authors attribute the difference in scuffing tendency between positions 1 & 3 and 2 & 4 to a difference in pushrod alignment. Could the authors elaborate on this conclusion, and would it not be desirable to eliminate this variable from the test machine? This has been done on the General Motors Research test machine.

AUTHORS' CLOSURE

While it is true that cam and tappet failures has been the subject of several papers in recent years, very little is disclosed in these papers about the relation between scuff failure and specific oil additives. Since it is generally accepted that field or dynamometer tests do not lend themselves to the determination of a single variable, we purposely limited the materials and operating conditions used in the bench test in order to evaluate the effect of the lubricant. We agree that hardenable cast iron tappets are relatively immune to surface distress in present day automotive engines. However, our results definitely indicate that hardenable iron tappets show response to lubricant additives when the tappets are run under more severe loading conditions. It is probable that automotive engines will approach these conditions soon.

The question of reproducibility of load-carrying results may be clarified by referring to the text of our paper: "Since Positions 2 and 4 appear to be more susceptible to scuff, they were used to evaluate the anti-scuff properties of the oil; the other two positions were used to evaluate the wear properties." The load-carrying results for Positions 2 and 4, shown in Figure 3, indicate a spread of only six hours for eight replicate runs. The anti-scuff results plotted in the subsequent figures of the first paper are based on data for Positions 2 and 4 only, which constitute duplicate tests.

Although the efficiency of "E.P.," "anti-wear agents," "sulfur-phosphorous" additives, or "Oil A, B, etc." have been mentioned in the literature as effective in scuff prevention, the article of Etchell *et al*[8] is the only one which mentions zinc dithiophosphate specifically. They found that zinc dithiophosphate prevented scuff of steel tappets run on alloy cast iron cams, whereas we found it effective for hardenable iron tappets run on alloy cast iron cams.

The experimental results obtained in our work tend to point up mating wear and lower unit stresses due to increase of contact area as important factors in scuff prevention; mechanisms such as anti-flux action from sulfur or phosphorus and the formation of a low shear strength 'E.P. film' on the metal undoubtedly play a role. The importance of these mechanisms awaits future investigations. It is not clear what is meant by the statement that "interpretation given to the proficorder tracings (Figure 8) is difficult to accept." We have simply shown how an increase in area of the mating surfaces can reduce the unit loading. This is not conjecture, because the actual area was measured by as precise a technique as we had available.

Mr. Robinson's remarks on the general agreement between the results obtained with the G.M. and Chrysler tappet test machines are encouraging. These testers, although basically similar, were developed independently and probably at about the same time. The superstructure mounted on the block of our tester controls the pushrod alignment. It is our belief that the present difference in pushrod alignment of Positions 2 and 4 compared to Positions 1 and 3 may account for the observed difference in scuffing tendency. A new model of our tester, which would permit variation of pushrod alignment, is in the planning stage.

It's Toronto in '57

ASLE-ASME 4th Lubrication Conference

October 7-8-9 Royal York Hotel

— SYMPOSIUM ON INDUSTRIAL DERMATOSES —
(Part 5 of a Series)

Prevention of Industrial Dermatitis in a Motor Truck Plant

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International Harvester has always been recognized as one of the leaders in the industrial safety movement. Harvester management has conscientiously accepted its responsibility for the prevention of industrial accidents. It feels an obligation to send each employe back to his home and family free from injury to his person or to his health. The company's formal program of industrial accident prevention dates back to 1908.

At first, safety activities were devoted almost entirely to the development of mechanical safeguarding. But increasing recognition of the importance of safety soon convinced top management that safety should become a definite part of management planning, not only for the prevention of accidents, but for all phases of working conditions that would affect the health and well-being of its employes. Today the same consideration is given to good sanitation and healthy working conditions as to the prevention of accidental injuries.

Industrial or occupational health hazards can be reduced to a minimum by the establishment of controls and the observance of these controls by all concerned. The greater the hazard, the more thorough and complete the control measure should be.

Each works has a safety committee which acts as a steering committee for the over-all safety program at that plant. It consists of the works manager, or his representative; the plant engineer; the mechanical engineer; the works safety supervisor, and an equal number of employe representatives.

There is also a committee composed of the works physician, the plant engineer, and the works safety supervisor, for the purpose of inspecting at regular intervals and making certain that the hygienic and sanitary conditions are satisfactory, and the employes adequately protected against all suspected or known occupational disease hazards.

Apart from accidental injury, industrial health hazards may be placed in two categories—known hazards and unknown hazards. The known hazards being the use or handling of cyanide, flammable or toxic material, working in tanks, pits, tunnels and so forth. Unknown hazards being coolants, solvents, cleaning compounds and so forth, commonly used, and proved to be harmless when properly used under normal conditions but, because of some unknown or unusual condition, have become contaminated or undergone a chemical change while in use that cause them to become a health hazard. This particular hazard can and often does contribute much to the cause of industrial dermatitis.

Another contributing factor to industrial dermatitis is the lack of necessary precaution in the selection of new agents, processes, and methods in manufacturing.

Before a new or unknown coolant, solvent, or lubricant is introduced into the plant, it is first examined by the Laboratory. After determining that it meets the requirements of our medical and plant protection departments, it is then placed on a trial basis in the shop under the supervision of the lubrication engineer. After the test has been completed, the trial product is either approved or disapproved by the Lubrication Approval Committee, which consists of the mechanical engineer, plant metallurgist, divisional superintendent involved, and the lubrication engineer.

With specific reference to metal cleaning sanitation, the chemical hazard encountered in this process is recognized as a major contributor to industrial dermatitis, and special handling is accorded this particular phase of manufacturing. The "Code of Recommended Good Practice for Metal Cleaning Sanitation," by the American Foundrymen's Association, Golf and Wolf Roads, Des Plaines, Illinois, is accepted and used as a guide.

Our laboratory is equipped with a pilot washer in which products and methods are checked before making a test on a production basis in the plant. Tests on a production basis are made by an analytical chemist in cooperation with and under the scrutiny of the divisional superintendent's office, general foreman and foreman involved, and the lubrication engineer. Final approval of the method or material is made by the Lubrication Approval Committee.

The classification of employes by the Medical Department for the purpose of restricting them from work which may be detrimental because of their particular health condition, contributes much to the prevention of dermatitis. It is not uncommon for a "class A" man physically fit for any job to be reclassified as the result of a subsequent examination into a "Group 4, class B," restricting him from working in dusts, fumes, and skin irritants.

Noble H. Schell

The environment in

This paper was presented at the ASLE 10th Annual Meeting, Chicago, April 13, 1955.

which men work cannot be overlooked. Clean, healthy, and safe surroundings are a must if we want quality products, good employe-employer relations, and community respect.

Sometime ago, we put in effect a plan to improve plant housekeeping. The purpose of this plan was to provide the cleanest, safest, healthiest place to work possible—to have employes think "safety and good health" on the job, and obtain high quality products.

Under this plan, each department is inspected once each week by a good housekeeping inspector who, accompanied by the department foreman, inspects and grades the department. Each department has a bogy of 100 points from which a penalty of from 1 to 5 points is assessed for each violation, such as: (a) aisles congested, (b) benches disorderly, (c) bins or racks not clean, (d) bottles not in proper containers, (e) clothing strewn about carelessly, (f) dock area disorderly, (g) stacks out of line, (h) electric equipment blocked, (i) drinking fountains not clean, (j) exhaust dust box not emptied recently, (k) fire apparatus blocked, (l) flammable liquids in unsafe containers, (m) machines not reasonably clean, (n) floor not reasonably clean, (o) nails in boards, boxes, or kegs, and (p) toilet or locker rooms not clean.

The inspector's report is given to the general foreman, with a copy to the divisional superintendent who compiles a divisional report and forwards it to the safety supervisor for recording purposes.

Good housekeeping winners are announced weekly.

An important feature of this plan is that it places good housekeeping on a competitive basis between employes and departments. It is recognized that when an employe is ordered to keep himself and his working area clean, he probably will make an attempt at doing that because his "boss" told him to. Yet, the employe's heart probably will not be in that part of his work. However, if the same employe finds that the cleanliness, orderliness, and safety condition in his working area is in competition with other working areas in the plant, the chances are that he will do his utmost to make and keep his area the best. Orders from the "boss" are not necessary because personal pride takes over. They know a clean place to work is a safe place to work.

Since this program was put in effect, coolant hygiene is no problem. Trash or garbage disposal cans, ash trays, and spittoons are placed at strategic locations. It is actually more convenient and inviting to throw a banana peel, apple core, a chunk of sandwich, or a candy wrapper in the disposal can than in the coolant tank. We have also found that men actually prefer spittoons to coolant tanks. Contaminants of this kind have been entirely eliminated by good housekeeping. Other contaminants, such as grinding dirt, chips, and extraneous oil are taken care of by a simple method of coolant control.

Recognizing that while in use, coolants—emulsions in particular—undergo a continual change in relative composition, a simple method of coolant control was put into effect. This simple method, while it is not everything that could be desired, regulates the frequency of cleaning machines, keeps emulsions at recommended concentration, reveals leaky hydraulic and lubricating systems, improves health conditions, and more than pays for itself through increased tool life and reduced maintenance cost.

Two men are employed in daily sampling and inspection of water-soluble coolants. It is their duty to observe the general condition of the coolant and coolant system, noting such conditions as discoloration, odor, oil leaks, excessive amount of grinding dirt or chips; take samples from the machines; and check the pH, concentration, and sediment.

If bad odor, considerable discoloration, or excessive sediment is observed, the foreman responsible for the machine is advised to have it cleaned out as soon as possible. Germicides, or masking agents, are not used unless specifically recommended by the vendor supplying the coolant.

After the concentration has been determined, the amount of water or base required is calculated. This is then recorded in a book in the Lubrication Engineer's office. A separate sheet is provided in this book for each machine. This is also recorded on a sheet posted in the department. The foreman is advised of machines that are not at the recommended concentration and instructed how much base or water to add. The machines requiring correction are again checked after about an hour.

When the pH value is found to be incorrect and the correction of the concentration does not adjust the pH, the coolant is replaced and an investigation as to the cause is made by the laboratory and the lubrication engineer.

Machines using insoluble oils are also checked at regular intervals. Samples are taken from the coolant spout to determine if fine metal particles are being circulated through the coolant system.

Gear-shaving machines and thread grinders are equipped with magnetic separators. Periodically the oil is taken from the machines and run through a steam heated settling tank for sterilization, and to remove fine metal particles.

Personal hygiene is encouraged by the provision of adequate locker rooms and attractive washing and shower facilities. The once-common habit of cleaning up with a shop rag and kerosene, or some other solvent, and that other bad practice of washing in the coolant, have disappeared almost entirely. There is a personal pride being shown in personal cleanliness.

In the foregoing, an attempt has been made to tell you of the methods used by International Harvester Company to reduce, if not eliminate entirely, industrial health hazards at the Fort Wayne Motor Truck Plant.

We do not intend to imply that this is the only solution. It is felt, however, that we are going in the right direction, and that the co-ordinated efforts of the company and its employes, careful selection of new agents, processes and methods in manufacturing, classification of employes by the Medical Department, good housekeeping, control of coolants while in use, and good personal hygiene, have all contributed in part to a record of no lost time from industrial dermatitis at a plant working nearly 10 million man hours in 1954.

ASLE-ASME 4th Lubrication Conference, October 7-8-9, Toronto

Application Problems with Petroleum Lubricants in Nuclear Power Plants

Various new fields of engineering have been developed to make possible nuclear power generating stations. Existing lubricants and lubricant technology will, however, serve most of the needs of this type plant. Pumps, turbines, and generators will operate with much the same lubricants, with the same bearing materials, the same bearing loads, the same speeds, and at the same temperatures as those in our present central stations. This paper will consider, then, the behavior of petroleum lubricants under irradiation and outline the general problems anticipated with lubricants in the components of nuclear power plants.

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INTRODUCTION

The presence of high energy radiation is the primary new feature in the maintenance of atomic power plants. Although most of the problems involved will be of a minor nature, the following exceptions will require some attention:

(1) There will be reduced accessibility to the lubricants and lubricated equipment for maintenance and inspection.

(2) There will be a reduction in the lubricant life in components that are very close to the reactor.

(3) The possibility of radiation damage must be considered with respect to other components of the lubrication system such as hoses, gaskets, and paint.

For many years we have been concerned with the physical, mechanical, and chemical properties of lubricating oils as they are affected by the molecular structure, temperature, pressure, and their environment. The tremendous quantities of data that are available on these properties give us satisfactory engineering information for applying lubricants to any given component in a conventional power plant. For nuclear power plants, the new radiation factor must also be taken into consideration.

BEHAVIOR OF LUBRICANTS UNDER IRRADIATION

Radiation damage to organic lubricants in a nuclear power plant is due primarily to ionization as a secondary effect from bombardment by fast neutrons, slow or thermal neutrons, and gamma rays.[2] Fast neutrons cause damage by interacting with the hydrogen nuclei in the organic materials and ejecting the hydrogen atoms as fast recoil protons. These protons then cause radiation damage by upsetting the electronic system of the molecules and producing ionization. Photons of gamma radiation collide with single electrons of the atoms of organic materials, transferring a portion of their energy with each encounter. These electrons are ejected and again there is an upset of the electronic system of the molecules with ionization. Deprived of an electron, the molecule becomes an unstable ion and can undergo a variety of chemical changes including polymerization and oxidation. Damage to organics by thermal neutrons results primarily from the capture of these neutrons by the nuclei of hydrogen atoms with the subsequent emission of high energy gamma rays.

Beta radiation (electrons ejected from atomic nuclei) and alpha particles (charged helium nuclei) would cause similar damage to petroleum lubricants. These radiations present no problem in the lubrication of a nuclear plant, however, since they are almost completely absorbed by the fuel, coolant, structural material and primary shielding of

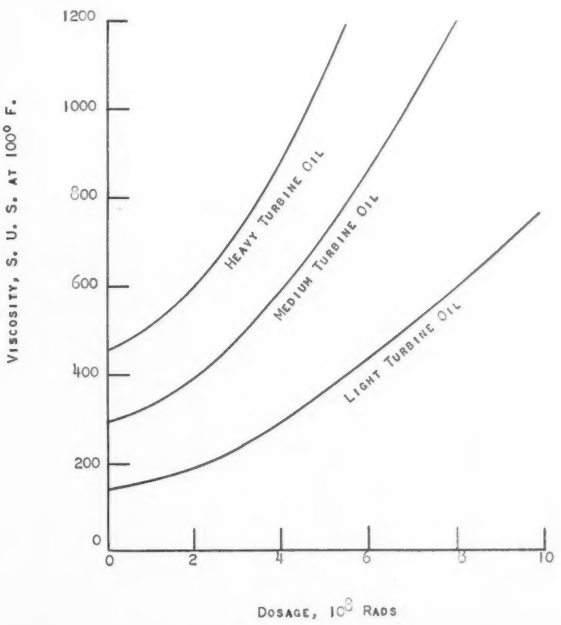

Figure 1. Effect of radiation on turbine oil viscosity (from correlation in Ref. 2).

the reactor itself. Alpha radiation is so readily absorbed, for instance, that an ordinary sheet of paper would stop essentially all alpha particles of radioactive origin.[3]

Both neutron and gamma irradiation degrade oils, as they do all other organic materials. However, oils do seem to have a certain period during which there is only a relatively minor change in their general physical properties while they are being irradiated. This period finally terminates at some threshold point, or engineering tolerance limit, beyond which the oil suffers substantial damage. When an oil has increased in viscosity by 25% of its original value, one may say that it has crossed the threshold into severe damage.

The generally permissible damage level for conventional lubricating oils is encountered at a dosage of about 1 to 2 $\times$ 10^8 rads. Since a rad corresponds to an energy absorption of 100 ergs per gram in any material, this radiation dosage corresponds to an absorption of 1 to 2 $\times$ 10^{10} ergs per gram of oil. Beyond this exposure level, lubricants and hydraulic fluids will exhibit appreciable viscosity change and other degradation effects which interfere with their satisfactory operation. The rapid increase in the viscosity of turbine oils when they are exposed to radiation doses above 2 $\times$ 10^8 rads is indicated in Figure 1.

Operation can be carried to somewhat higher dosages with organic fluids containing large portions of aromatics.[2] Alkyl benzene fluids have been used to produce oils with improved radiation resistance. With these and similar aromatic structures, the absorbed energy apparently goes to a large extent into resonant energy in the aromatic ring structure. This reduces the damaging ionization and free radical formation which occurs on a much more general basis with chain-like structures in paraffinic oils or in the saturated ring structure of naphthenic oils.

Synthetic oils vary somewhat in their resistance to radiation. Although the alkyl benzenes have better radiation stability, they do not provide as good lubrication in reactor tests as do the aircraft type diester oils or the polyglycol lubricants. Of these three types of oils, Bolt and Carroll[1] concluded that the polyglycol type was the most satisfactory for use in nuclear reactors from a radiation damage standpoint.

Although many advances remain to be made in the development of lubricants for atomic reactor systems, we are fortunate in having available even now sufficient information to guide us in initial applications and considerations of potential problems. The amount of radiation required to bring petroleum oils to their threshold of damage or engineering tolerance limit has been well established. Much of the future work will likely be directed at determining optimum equipment designs and lubrication systems to take into account this threshold value.

Table I
Radiation Effects on Lubricant Life
in a Typical Nuclear Power Plant

Components	Operating Dosage Level, Rads/Hr.	Lubricant Life, Hours To Attain 10^8 Rads Exposure
Turbine	0.2	10^9
Water Circulating Pumps	10^2	10^6
Remote Fuel Handling Devices	10^5	10^3
Control Drive Mechanisms	10^5	10^3
At Reactor Vessel Wall	10^6	10^2
At Reactor Core Center	10^{13}	10^{-5}

LUBRICATION OF A TYPICAL NUCLEAR POWER PLANT

The principal components in a typical nuclear power plant are indicated in the schematic diagram of a 12.5 megawatt single-cycle boiling-water reactor plant in Figure 2 and in the pictorial representation in Figure 3. As can be judged from the figures, many of the bearing and lubrication requirements are identical or very similar to those in conventional apparatus in use in our present fossil-fueled power generating stations. It should be noted that the following discussion is related primarily to one particular design of boiling-water power plant very similar to one which has been described elsewhere.[4] Although the general lubrication problems will be similar for most other types of nuclear power systems, individual equipment conditions will have to be considered separately in every case.

The calculated radiation levels which will be encountered by lubricants in the various components of the plant shown in Figure 3 are indicated in Table I. The radiation levels for the turbine-generator set, the pumps, and other devices external to the reactor shield itself are sufficiently low so that they will have little or no effect on the life of petroleum lubricants.

Control mechanisms within the reactor shield, however, and some of the remote fuel handling devices will be exposed to very large radiation doses. Use of any petroleum-base lubricant may be an impossibility in these cases, and resort must be made to judicious bearing material selections and design to permit lubrication by the coolant water. Since remote fuel-handling devices operate at low speed and are lightly loaded, water lubrication is not diffi-

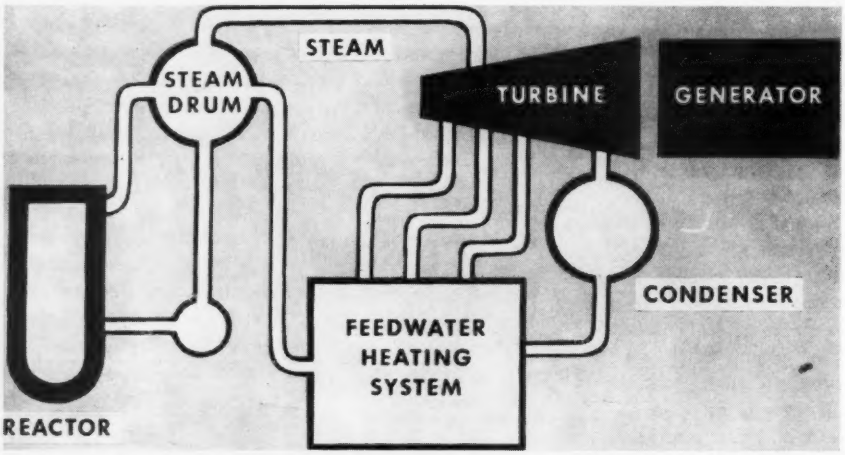

Figure 2. Schematic diagram of single-cycle boiling-water nuclear power plant.

Table II

Effect of Added Elements on Lubricant Activity
(Assumed exposure of 100 hrs. in thermal neutron flux of 3×10^8 neutrons/cm^2 x sec. Activity data for individual elements taken from Ref. 7.)

Additive, 0.1 Wt. % of Indicated Element	Calculated Lubricant Activity 10 Minutes After Shutdown	
	Microcuries/cc For Gamma Activity	Gamma Radiation At Oil Surface, r/hr.[b]
None	Negligible	
Oxygen	Negligible	
Nitrogen	Negligible	
Lithium	Negligible	
Phosphorus	Negligible[a]	
Sulfur	Negligible[a]	
Barium	0.02	0.001
Cobalt	0.06	0.01
Chlorine	0.02	0.02
Sodium	0.1	0.4

[a] Beta radiation emitted. No gamma activity.
[b] 1 r (roentgen) is the biological radiation unit equivalent to the absorption of 83.8 ergs per gram of air.[3]

cult. Friction and wear problems within the reactor core itself are, however, of a quite unusual nature. Water[5, 8] and liquid-metal lubrication have been the subject of much research and will be the continued center of extensive study as more reactors come into operation.

The most critical unit in normal power plant operation insofar as lubrication is concerned is the turbine and its associated generator. Although special design features will be incorporated in the turbines for nuclear power plant service, the speeds, bearing loads, and bearing materials will be identical to those in conventional power plants. The lubricating oils will also be identical, and paraffinic-type turbine oils of approximately 150 SUS viscosity at 100° F. will be used as before. The gamma radiation dose of about 0.2 rads per hour will result chiefly from nitrogen-16 which is formed by the absorption of neutrons in oxygen-16 nuclei within the reactor core. Some further slight gamma irradiation of the oil comes from the small amount of activated corrosion products carried from the reactor to the turbine.[6] As shown in Table I, oil would have to be exposed to this gamma flux for many years before its effect could be noticed. Since nitrogen-16 has only a 7.3-second half-life, this radiation dies out rapidly when the power plant system is shut down and will not interfere with maintenance operations on the turbine itself.

The bearings in the water-recirculating pumps are also outside of the protective shielding around the reactor and are subjected to a relatively low radiation level. Here again, gamma radiation from nitrogen-16 in the water stream is the primary consideration. The lubricant life is not adversely affected by the low level of radiation present as shown by Table I.

The radiation level around control rod drive mechanisms such as gears, motors, cams, and pivots external to the primary reactor shield, is moderate. In the system shown in Figure 3, some leakage neutrons as well as gamma rays emanating from the reactor will reach lubricants used on these drives. As indicated in Table I, the radiation dosage encountered in the lubrication of these parts is sufficiently high to warrant special lubrication procedures.

LUBRICANT DISPOSAL

Handling waste lubricants discharged from the lubrication systems around a nuclear power plant involves no problems so long as the oils are exposed only to gamma radiation. The turbine oil from the turbine-generator set, for instance, exhibits no radioactivity and can be handled in the same fashion as any other turbine oil.

Where the oils are exposed to radiation by neutrons, however, they may develop appreciable activity if metallic additives are present in the oil. Table II gives some indication as to the degree of gamma activity which could be expected in oils containing 0.1 weight percent of the indicated elements. These oils were assumed to have been exposed to radiation at the outside surface of the reactor shell for a period of 100 hours. This radiation was taken to consist of 4×10^{10} fast neutrons/cm.^{2}/sec., 3×10^8 thermal neutrons/cm.^{2}/sec. and 1×10^{11} gamma photons/

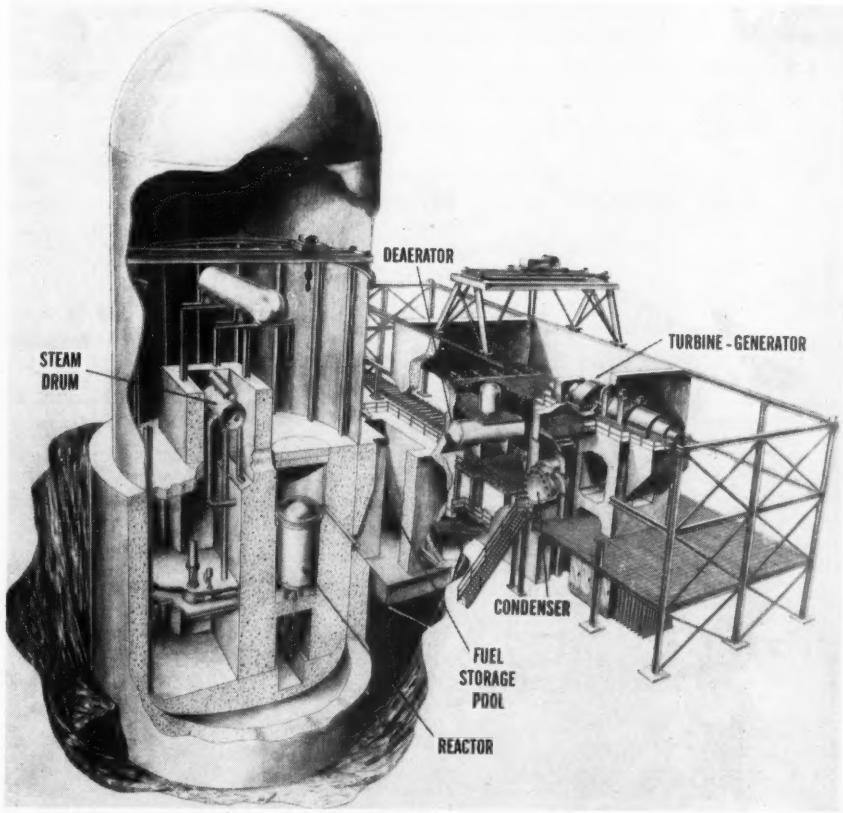

Figure 3. 12,500-KW boiling-water reactor electric generating plant.

cm.^{2}/sec.

From Table II, the handling of waste lubricants can be seen to be a slight problem, but the handling precautions necessary vary somewhat with the types of additives present. The maximum permissible dosage for humans is usually given as 0.3 roentgen in one week.[3] The activity at the surface of the irradiated oil is seen in Table II to be considerably less than this for almost all usual-additive elements after a 10-minute decay period. In general, detergent-type and rust-inhibited oils with metallic additives such as sodium should be avoided unless their use is necessitated by some unusual lubrication demands. The activity for other added elements in oil can also be estimated under these and other dosage conditions from published nuclear data.[7] Even with sodium and other similarly activated additives, however, there will be no problem so long as the oil is not exposed directly to neutron flux close to the reactor itself.

Beta particles would also be released from irradiated oils containing some types of additives. Only the highest-energy beta particles are able to travel more than a few millimeters in body tissue,[3] however; and beta emission generally offers no hazard so long as good housekeeping and personnel cleanliness procedures are maintained.

Any lubrication maintenance work by operating personnel required during reactor operation presents a more difficult problem. The level of radioactivity around the turbine, at circulating pumps, and at control rod drives is sufficiently high during running that safe work on them may be possible (depending on the design of the plant and its components) only for very short periods or from remote locations behind either protective concrete or other biological shielding. Automatic or remotely operated lubrication equipment should, therefore, be employed in such circumstances.

METHODS FOR MINIMIZING RADIATION PROBLEMS

The three following steps should be taken to minimize lubrication problems in nuclear power stations:

(1) Adequate shielding should be provided between the reactor and components requiring petroleum lubricants to minimize radiation damage.

(2) Lubricants should be carefully specified so that only stable oils will be used which will have the necessary lubricating properties and which will offer a minimum problem if they are exposed to neutron irradiation.

(3) Relubrication periods should be scheduled so that oils will be taken out of service before they reach the threshold period beyond which damage would result from continued exposure.

With these steps, the over-all lubrication problems in a nuclear power plant will be very similar to those encountered in conventional steam power generating stations. Thermal and oxidative degradation conditions will be similar for petroleum lubricants in the two types of stations. The same general types of oils and greases will be employed, the relubrication schedules and inspection periods will be similar in length, and only minor attention must be paid to the possibility of the build-up of radioactive contaminants in the oil. The problems will vary only slightly with the type of nuclear power plant system employed since there will be the same general types of equipment to be lubricated and the radiation shielding will be similarly arranged for ready maintenance of the equipment.

To reap the full benefits of our coming nuclear age, we must learn to live with some of the new variables we have created. The problems involved in designing, operating, and maintaining the lubrication systems of our nuclear power plants will likely seem insignificant ten years from now. It is hoped that this survey will ease us through our early exploratory steps.

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Solid Lubricants for Temperatures to 1000° F.

Yellow lead oxide, PbO, several other heavy metal oxide powders, and other materials were studied as possible solid lubricants in low-speed (5.7 ft./min.) kinetic-friction experiments. At 1000° F., with cast Inconel slider specimens and Inconel X disk specimens, PbO was by far the best lubricant of the materials studied. A typical friction coefficient was 0.09 at temperatures of 900° F. and higher. Higher friction was obtained with decreasing temperatures.

In the temperature range between 700 and 900° F., PbO is converted to Pb_3O_4. At temperatures above 1000° F., Pb_3O_4 reverts to PbO. The friction coefficient is increased in proportion to the amount of Pb_3O_4 in the PbO.

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INTRODUCTION

Because the operating temperatures of gas turbines and other aircraft engines are continually increasing, it will be necessary to lubricate sliding parts at temperatures that may be considerably above 1000° F. The use of solids as lubricants offers one of the most promising approaches to high-temperature lubrication problems.

In previously reported research,[1-3] efforts have been made to establish important criteria for effective lubrication with solids. Low shear strength is important for minimum friction with solid lubricants. Soft materials or materials with certain types of crystalline structure[1] may give low shear strength. Possibly the most important criterion for a solid lubricant, however, is that it should become firmly attached by chemical or mechanical means to the surface being lubricated. Further, the solid must be chemically stable at the operating temperatures. The usefulness of the most common of solid lubricants, molybdenum disulfide (MoS_2) and graphite, is limited, because they begin to oxidize in air at temperatures of about 750 and 850° F., respectively.

Several of the heavy metal oxides appear to fulfill these rather general requirements for solid lubricants. They are chemically stable at temperatures to 1000° F. and higher, although at least one material is subject to phase transformation at lower temperatures. Also, they are soft materials and, thus, may have low shear strength and the ability to flow plastically. This characteristic would help establish the intimacy of contact that would contribute to good mechanical adhesion. The affinity of various metal oxides for one another is demonstrated by their phase diagrams.[4] Therefore, it should be expected that they might adhere well to the normal oxide films present on the metallic surfaces to be lubricated. Further, many investigators have shown that certain oxides are beneficial when formed "in situ" or developed during "run-in".[5-7]

The objective of the research reported is to determine the lubricating effectiveness of yellow PbO and of several other heavy metal oxides at 1000° F. The oxides included in this research are PbO, Pb_3O_4, Bi_2O_3, CdO, In_2O_3, WO_3, Sb_2O_3, and PdO. The most promising of the oxides (PbO) was studied in greater detail than the others. Some comparative data on materials other than oxides were obtained.

Data were obtained in low-speed kinetic-friction experiments in which the solid was usually applied as a dry powder.

MATERIALS, APPARATUS & PROCEDURE

LUBRICANTS

The solid lubricants and the method of application are listed in Table I. Those materials (with the exception of talc), which are designated "powders," were pure reagent grade materials; those designated "evaporated" were prepared by oxidation (under suitable conditions) of a thin

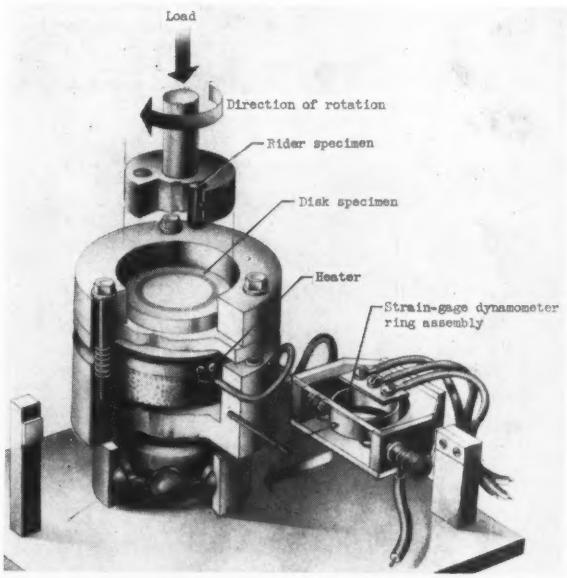

Figure 1a. Friction apparatus, diagrammatic sketch.

This paper was presented at the 3rd Annual ASLE-ASME Lubrication Conference, Atlantic City, October 8-10, 1956.

0.0001-inch-thick film of metal which had been evaporated onto the disk specimen.

Test Specimens

The solid lubricants were used to lubricate metal specimens, which consisted of cast Inconel riders sliding on an Inconel X disk (diam., 2½ in.; thickness ½ in.). The rider specimens were cylindrical (diam., ⅜ in.; length ¾ in.) and had a hemispherical tip (rad. $\frac{3}{16}$ in.) ground on one end. The test surface of the disk was ground flat and then vapor-blasted.

Apparatus

The apparatus shown diagrammatically in Figure 1a is essentially the same as described in References 8 and 9. In this investigation, three hemispheres (rad. $\frac{3}{16}$ in.) were caused to slide against a flat disk in a single circumferential path. The hemispheres were mounted in a holder to which vanes had been attached in such a way that the lubricant would be continually returned into the path of the sliders (Fig. 1b). The slider holder was clamped in a universal chuck mounted on a spindle which could be raised, lowered, or locked in any position. The disk was placed on a support table and kept from rotating by means of a locating pin in the support table. A heater was mounted under the support table. A ball bearing in the base of the apparatus allowed free movement and had a negligible effect on the total friction force. The friction force was measured by restraining the lower assembly through a dynamometer ring on which strain gages were mounted. The maximum force measured by the strain indicator as used for these experiments gave a friction coefficient of 0.41; any greater values were therefore not recorded. Temperatures were measured by a thermocouple mounted on the bottom of the disk.

Table I — Coefficients of Friction for Various Lubricants at 1000° F.

[Lubricants listed in order of decreasing lubricating effectiveness]

Lubricant	Method of application	Coefficient of friction	MHO hardness at room temperature (a)	Surface condition after test
None	.....	>0.41	.....	Severe galling
PbO	Powder	0.08-0.12	2	Nearly continuous lubricant film; no damage
PbO	Evaporated metal film, then oxidized	0.07	2	Nearly continuous lubricant film; no damage
Pb_3O_4	Powder	0.21	2.3	Discontinuous film; some metal contact; some rider wear
Ag	Evaporated	0.25	.....	Film worn and penetrated, allowing contact of base metals
Bi_2O_3	Powder	0.31	.....	Very thin film with local metal contacts, formed after some galling
CdO	Powder	0.34	3	Very thin film with local metal contacts
In_2O_3	Evaporated metal film, then oxidized	0.36	.....	Very thin film with local metal contacts
WO_3	Powder	>0.41	2.5	Failed surface; galled
Sb_2O_3	Powder	>0.41	2.5-3	Failed surface; solid flowed plastically to form irregular film, allowing metal contact
PdO	Powder	>0.41	.....	Severe galling
BN	Powder	>0.41	.....	Severe galling
Talc	Powder	>0.41	1-1.5	Severe galling

(a) Handbook data

The support table rested on three springs which compensated for minor alinement of the sliders and disk. The load was applied by lowering the spindle and compressing the base springs. The magnitude of the load was indicated by a dial gage measuring spring compression, which had previously been calibrated using dead weights.

Cleaning Procedure

Prior to each run, and before the deposition of special evaporated metal films, both the disk and the slider specimens were cleaned according to the following procedlure: (1) washed in a solution of 50 percent acetone and 50 percent benzene; (2) scrubbed with repeated applications of moist levigated alumina; (3) washed in tap water; (4) washed in pure acetone; (5) dried in dry air.

Test Procedure

The cleaned test specimens were placed in the apparatus, and enough of the powdered solid was added to cover the disk to a depth of about ¼ inch. A load of 40 pounds was applied, and the temperature brought to the desired level. The test was begun, and the friction force was measured for at least 2 hours. With the oxidized evaporated film, no additional powder was used.

RESULTS

Lubrication with Metal Oxides & Other Compounds

The coefficients of friction for the soft metal oxides and other stable compounds after 5 minutes sliding at 1000° F. is shown in Table I; the mho hardness and the method of application are also shown. The compounds are arranged in decreasing order of their effectiveness. There seemed to be no relation between the mho hardness and the lubricating effectiveness of the materials. PbO was the only material tested which gave a low coefficient of friction

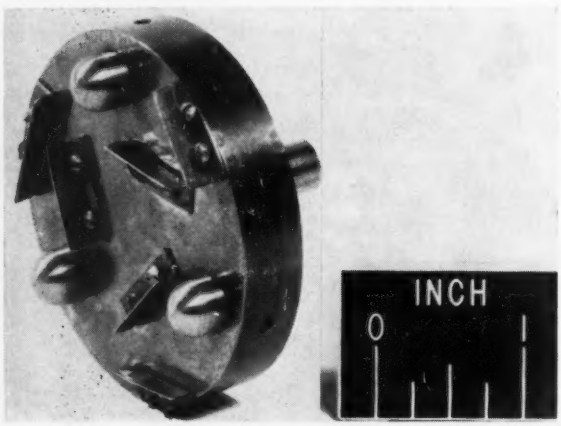

Figure 1b. Friction apparatus, rider specimen holder.

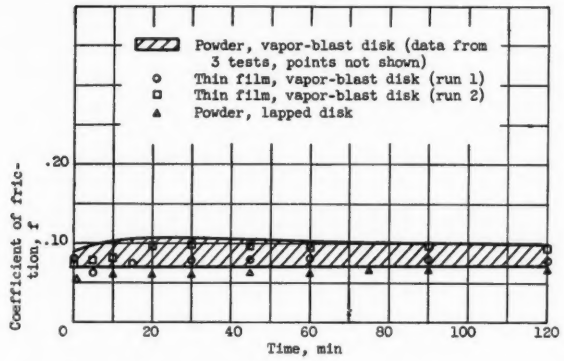

Figure 2. Effect of sliding time on coefficient of friction of cast Inconel sliding against Inconel X, using PbO as a lubricant. Load, 40 pounds; sliding velocity, 5.7 feet per minute; temperature, 1000° F.

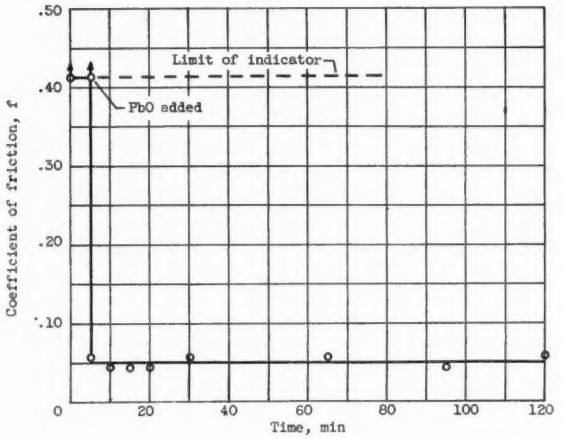

Figure 3. Effect of sliding time on coefficient of friction of cast Inconel sliding against Inconel X, with PbO added as a lubricant after 15 minutes sliding. Load, 40 pounds; sliding velocity, 5.7 feet per minute; temperature, 1000° F.

and also formed a nearly continuous surface film. Several other oxides had film-forming tendencies, but did not give as low friction as PbO.

Lubrication with PbO

Since PbO was an effective lubricant at 1000° F., further tests were run in order to determine the extent of its usefulness. Its friction-time curve is shown in Figure 2. The band represents the spread of data for three repeated tests with powder on vapor-blasted disks. The coefficient of friction is essentially constant (0.07 to 0.1) after 1-hour sliding time. The friction coefficients for the evaporated film fall within this scatter band.

When lapped surfaces (≈ 15 rms) were used instead of the more rough vapor-blast surfaces (60 rms), the friction coefficient was lowered slightly as shown by the triangular symbols in Figure 2.

A very severe test of the effectiveness of a solid lubricant can be obtained if the test materials are first run without lubricant at the desired temperature. The solid is then added, and changes in friction are noted. If the lubricant is effective under these adverse conditions, it should be even more efficient under more favorable conditions. Such a test was run with PbO at 1000° F., and the results are shown in Figure 3. The coefficient of friction for cast Inconel sliding against Inconel X is high (above limit of indicator); when PbO was added, the friction coefficient dropped to 0.05 and smooth sliding occurred.

Effects of Varied Temperature on PbO

Tests were run to determine the temperature range of PbO effectiveness. Two types of tests were used. In one type, friction was recorded in separate tests for 2 hours of running time at each of various temperature levels. The coefficient of friction after 2 hours is plotted against temperature in Figure 4; these points are represented by the circular symbols. The friction coefficient was high at room temperature and decreased as the temperature level was increased to 1000°F. The trend for friction to decrease as temperature was increased was considered a result of shear strength being reduced by higher temperatures. Other factors may also be important. At no temperature was any serious surface damage apparent. It should be noted, however, that no runs of this type were made at temperatures between 400 and 1000° F.

In the second type of test, the specimens were run for 2 hours at 1000° F., then friction was recorded as temperature was allowed to decrease while sliding continued. (Cooling to approximately 200° F. required about 2½ hr.) A representative test is shown in Figure 4, where data points selected at random intervals are shown as square

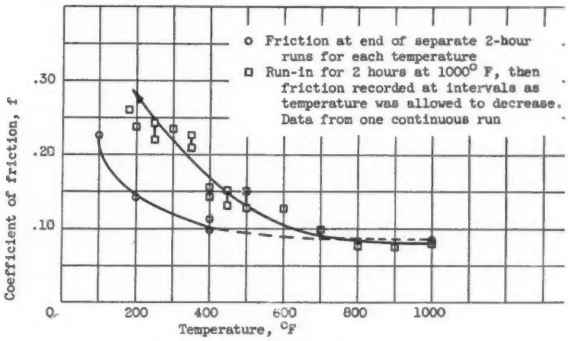

Figure 4. Effect of temperature on coefficient of friction of cast Inconel sliding against Inconel X, using PbO as a lubricant. Load, 40 pounds; sliding velocity, 5.7 feet per minute.

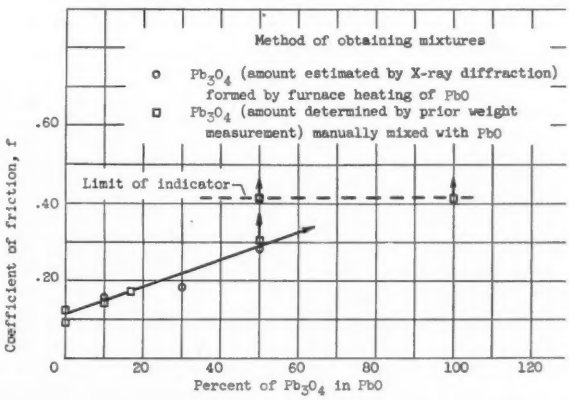

Figure 5. Effect of weight percentage of Pb_3O_4 in PbO on coefficient of friction for cast Inconel against Inconel X. Load, 40 pounds; sliding velocity, 5.7 feet per minute; temperature, 400° F.

symbols. These data show that after PbO had been run at 1000° F. for 2 hours it gave higher friction when cooled to lower temperature levels than if the runs had been made without previous heating to 1000° F. This result suggests that PbO would be more effective in runs with increasing temperature levels than with temperatures decreasing from 1000° F. X-ray diffraction analysis showed that Pb_3O_4 was present in samples of PbO that had been run as a lubricant at 1000° F. and then cooled to room temperature, Friction experiments were conducted to determine whether Pb_3O_4 contamination in PbO was detrimental.

Effect of Presence of Pb_3O_4 in PbO

Various percentages of Pb_3O_4 were added to PbO, and the friction-time curves for the mixtures were obtained at 400° F. In Figure 5, the average value of the friction coefficient after run-in is plotted against percentage of Pb_3O_4. Also plotted are average friction coefficients for additional tests prior to which the PbO had been partly converted to Pb_3O_4 by heating. The PbO was heated in a furnace at 1000° F. for 3 hours, then cooled to 400° F. and held at that temperature for ½ hour. Some PbO was converted to Pb_3O_4 during the cooling cycle, particularly in the temperature range from 700 to 900° F.[10] The cooling rate determined the percentage of PbO converted to Pb_3O_4. The powder was transferred to the friction apparatus, which had been preheated to 400° F., and the run was begun. The amount of Pb_3O_4 present in the furnace-treated PbO was estimated from X-ray diffraction pattern intensity measurements. These data show that the presence of Pb_3O_4 is harmful. The coefficient of friction increases gradually up to 30 percent addition. Above 30 percent, friction values were higher and more erratic; friction increased beyond the limit of the indicator during the course of the run.

These results explain the increase in friction after run-in at 1000° F. (Figure 4). Within the temperature range from approximately 700 to 900° F., some of the PbO was converted into Pb_3O_4; this caused a corresponding rise in friction.

DISCUSSION

At 1000° F., yellow PbO proved to be the most effective solid lubricant included in this investigation. At room temperature, however, PbO gave higher friction than would usually be acceptable for a lubricant. In experiments of the type described herein, PbO gave slightly lower friction at 1000°F. (Figure 2) than graphite in the data reported in Figure 2 of Reference 9. PbO was relatively stable at 1000° F., while graphite oxidized readily; thus PbO would have the longer useful life. Both materials were effective in preventing surface damage to the slider specimens during short experiments.

The ability of PbO to lubricate may result from its observed tendency to form adherent films on the metal surfaces. It is believed that chemical reaction or solubility of PbO with the base metal or, possibly more important, with its oxide film,[4] contributes to the formation of adherent films.

On heating PbO in air, the formation of Pb_3O_4 occurs at temperatures between 700 and 900° F.[10] The presence of Pb_3O_4 has an adverse effect on the lubricating ability of PbO as determined by friction measurements. When formed in PbO, Pb_3O_4 appears to act as an abrasive and tends to remove the PbO film formed on the metal surface. At temperatures above 1000° F., the Pb_3O_4 reverts to PbO which is the stable form at high temperatures. Because of this reversion, a high-temperature mechanism may be lubricated effectively by PbO even though cycling at temperatures lower than 900° F. does occur.

For special applications involving temperatures above 900° F., PbO may be used as a lubricant. For temperatures below 700° F., other solids such as MoS_2 are better solid lubricants than PbO. The maximum temperature for effective lubrication with PbO was not established. In these tests it was higher than the maximum temperature obtainable (≈ 1100° F.) with the present apparatus. The melting (or decomposition) temperature of PbO (≈ 1600° F.) would be the absolute maximum limit of usefulness. It is, however, corrosive to some metals, and in those cases the limit of tolerable corrosion might establish the maximum useful temperature. Also, Reference 9 shows that it reacts chemically (was reduced to metallic lead) with graphite at a temperature of 850° F. As with most lubricants, the manner in which it is used will determine the limit of its usefulness.

The potential of PbO as a solid lubricant is very likely greater than indicated by the experiments reported. The formation of Pb_3O_4 can be inhibited in several ways. First, it is possible to incorporate PbO into a binder that would serve as an oxidation barrier and reduce the amount of Pb_3O_4 formed. Second, it may be possible to find a suitable additive which would inhibit the transition from PbO to Pb_3O_4.

CONCLUSION

An experimental study was made of several solids as possible high-temperature solid lubricants using a low-speed (5.7 ft./min.) kinetic-friction apparatus. The following results were observed:

(1) Lead oxide PbO was by far the most effective of several oxides of heavy metals as a solid lubricant at 1000° F. The friction coefficient was 0.09 for PbO lubricating a cast Inconel slider on an Inconel X disk at 1000° F. Higher friction was observed with decreasing temperatures (below 900° F.). At room temperature, PbO gave higher friction than would usually be acceptable for a solid lubricant.

(2) In the temperature range between 700 and 900° F., some of the PbO was converted to Pb_3O_4. At temperatures above 1000° F., Pb_3O_4 reverts to PbO. The Pb_3O_4 caused increased friction coefficients in proportion to the amount present in the PbO.

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COMMENTARY

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This paper certainly is a significant contribution to our knowledge of how to attain satisfactory lubrication at temperatures far above those at which we are accustomed to work.

In the initial discussion, the authors say that "the most important criterion for a solid lubricant . . . is that it should become firmly attached . . . to the surface being lubricated." Is there any direct experimental evidence, apart from the low friction coefficient of this good adhesion, in the case of PbO?

It is suggested that the undesirable conversion of PbO to Pb_3O_4 might be inhibited by a protective binder which would serve as an oxidation barrier, or by an additive which would slow down this conversion. The first alternative seems unlikely since only the PbO protruding from the binder will serve to lubricate the rubbing surfaces. Unfortunately, this exposed portion, which is the only part really needing protection, is just the part that the binder will not protect from the air. It seems simpler to just exclude air by blanketing the rubbing surfaces with inert gas or fuel vapors (as has recently been suggested for other lubricant systems).

Also, would a mixture of PbO and metallic lead serve as a good lubricant in this temperature range? The metallic lead might serve as a reducing agent to prevent the formation of Pb_3O_4 until almost all of the metal had been converted to the lower oxide PbO, thus lengthening the useful life of the lubricant.

AUTHORS' CLOSURE

The adhesion of PbO to metal surfaces has been demonstrated experimentally by the endurance properties of the lubricant film. A surface glaze was observed to form during sliding and, without subsequent addition of PbO, the film would continue to lubricate for significant periods of time. The glaze film was usually continuous and could not be flaked from the surface; abrasion was necessary for removal of the film.

Oxidation rate is a function of surface area of the particles being oxidized. A protective binder would simply reduce the surface area of PbO available for oxidation. Pb_3O_4 appears to act as an abrasive to disrupt the PbO film. Thus, any means of reducing the quantity of Pb_3O_4 in the bulk film as well as at the interface should help to sustain effective lubrication. Particles of PbO at the interface would, of course, remain subject to surface oxidation. It has been demonstrated (Ref. 1, pages 20, 58 & 59) in the case of MoS_2, however, that even with the surface interface completely oxidized, shear will occur below the oxidized layer and, thus, effective lubrication can be obtained.

The experience of Reference 2 with mixtures of PbO and graphite would suggest that PbO and metallic lead could serve as a good lubricant at 1000° F. Reference 2 reports that at 850° F., a reduction reaction occurred between PbO and graphite. This reaction produced some metallic lead. However, unreported data showed the mixture, including increasing amounts of lead and decreasing amounts of Pb and graphite, continued to lubricate effectively at 1000° F.

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Technical Services Abstracts

(The following reports of research for the Armed Forces have been recently released for industry use, and may be obtained at the prices indicated by writing: Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.)

Plastic Roller Bearing Race Separators — Critical Operating Properties of Plastics, by A. Gremer, Schweinfurt, Germany, June 1955; translated by Science Translation Service, University of Alabama, for Bureau of Ships, U. S. Navy; 25 pages. Plastic bearings have been widely substituted for those of metal in German industry because of superior "critical operating properties," defined as the operating behavior of bearing materials under such unfavorable conditions as failure of lubrication, high local loading because of improper installation, and excessive RPM's. The outstanding properties of plastic bearings led to tests of the suitability of plastics as roller bearing race separators. With a few exceptions, the five plastics investigated exhibited considerably better critical operating properties than bronze or steel commonly used in the separators. (Order No. PB-121363, price 75c)

Roller Bearing & Friction Bearing Technology for the Designer, by K. Kollman &. H. Hahn, Karlsruhe, Germany, April 1955; translated by Science Translation Service, University of Alabama, for Bureau of Ships, U. S. Navy; 26 pages. This volume contains papers presented at a convention of the Stuttgart unit of the Study Group of Design Engineers held in October 1954 to acquaint industrial designers with results of the latest research in roller and friction bearing technology. Included are reports of research on roller bearings entitled "Bearing Capacity & Life Duration of Roller Bearings"; "Design Problems in Designing of Recent Roller Bearing Systems"; and "Friction & Lubrication of Roller Bearings." Those on friction bearing technology are "Newer Viewpoint of the Phenomenon of Lubrication"; "The Phenomenon of Mixed Friction and Its Effect on the Boundary Loading of a Friction Bearing"; "The Calculation of the Temperature of Friction Bearings"; and "Highly Loaded Friction Bearings." (Order No. PB-121366, 75c)

Starting & Running Low Temperature Torques, by B. Rubin, Wright Air Development Center, May 1956; 22 pages. A procedure proposed by an ASTM technical committee for including starting and running torque requirements in grease specifications was tested. The procedure would replace a method used for procurement of low temperature greases for military aircraft. The present method has been said to lack effective correlation with service application and adequate sensitivity for measurement of torque variation of the many different modern synthetic greases. To test the proposed procedure, low temperature (minus 65° F.) starting and running torque data were obtained for sizes 104, 204, and 306 bearings. Test procedures, data obtained, and a statistical study are included in the report, along with recommendations for improvement of the procedure for specification purposes. (Order No. PB-121440, price 75c)

Evaluation of Chlorophenyl Phosphates as Potential Base Stocks for High-Temperature Hydraulic Fluids, by J. C. Dacons & H. M. Schiefer, Wright Air

(Continued on p. 243)

A New Method for the Determination of Attitude & Eccentricity in Journal Bearings

This paper reports on a new method for measuring attitude and eccentricity in journal bearings. The principle is to measure the motion between a rigidly supported shaft and a floating bearing. Three types of instruments were used to measure this motion. Since the work was done in conjunction with a stability analysis of journal bearings, only eccentricity ratios in the range from 0 to 0.5 were investigated.

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INTRODUCTION

Some of the most difficult yet most important measurements to be made in bearings are those of determining the attitude, eccentricity, and film thickness. These measurements are extremely important for application and verification of the hydrodynamic theory of lubrication and for the analysis of the stability of journal bearings. From a practical standpoint, it is very important to determine the minimum film thickness for given load and operating conditions. The minimum film thickness establishes limits on the maximum size of particles that may be tolerated in the lubricant supply system, the degree of filtration necessary, and other important bearing design factors such as the necessary surface finish, the rigidity of the journal-bearing system, and the need for self-aligning bearings and the like.

Many efforts have been made to measure attitude, eccentricity, and film thickness in bearings. A large number of ingenious devices have been used for this purpose. A review of the literature was made before instituting the tests that are reported in this paper, and 28 references on the subject were collected. These references are included in a list at the end of the paper. In general, previous investigators have attempted to measure the relative motion between a rigid bearing and a flexible shaft. Instruments used fell into 4 categories: (a) mechanical, (b) electrical, (c) optical, and (d) pneumatic. The mechanical group includes such instruments as dial gages and micrometers. The electrical group consists of transformers, capacitors, reluctance pick-ups, and similar instruments. The optical group encompasses microscopes and other optical equipment employed to magnify the motion of the shaft in its bearings. The pneumatic group includes a variety of air gages and air flow devices designed to measure, by means of flow variation, the relative position of the shaft and bearing.

These are very difficult measurements to make, and it is not surprising to find that the results of these numerous investigations and the various methods that were employed show little agreement. Figure 1 compares the results of many experiments.

The one aspect common to most of the previous experiments consisted of a rigidly mounted bearing and a floating shaft. It was necessary then to measure the motion between the rigid bearing and the floating shaft. Thus, when mechanical means were used to measure attitude and eccentricity, the device such as a dial gage was mounted rigidly to the bearing, and the plunger of the dial gage pressed against the rotating shaft. This apparently has introduced quite some error for there may always be the possibility of vibrations and dimensional changes developing at the point of contact with the rotating shaft. In some instances, a hydrodynamic film has developed between the plunger and the shaft. In other cases, a film was not developed but apparently wear took place.

EXPERIMENTAL PROCEDURE

After some consideration, it became apparent that these experimental measurements might be conducted with a reversed procedure from the usual approach. For example, the bearing might be permitted to float in conjunction with a shaft mounted rigidly in high precision zero

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This paper was sponsored by the ASLE Technical Committee on Bearings & Bearing Lubrication, and presented at the ASLE 10th Annual Meeting, Chicago, April 15, 1955.

internal clearance ball bearings, so that the shaft would have no radial movement when rotating. By using this technique, one has the advantage of being able to measure the motion of the non-rotating bearing. If we consider the shaft and the bearing axis at zero load as the z axis, then as the shaft rotates in its ball bearings and as load is applied, the floating bearing can move on the x and y axes.

If measuring instruments are mounted rigidly to some datum line and they are positioned on the x and y axes, they then can measure the bearing motion.

This, of course, does not imply that the instruments measure the relative motion between the shaft and the bearing in the x and y direction, for there is the possibility that the shaft may also be deflecting or moving in the radial direction. It is also necessary to determine the absolute motion of the shaft and, knowing this, to then determine the relative motion between the shaft and bearing.

A design was made to insure that the shaft did not deflect appreciably and did not have radial motion in the bearing. By making the shaft very short and stiff, the deflection under the light loads, which were of interest, could not be measured with a 0.00005″ dial indicator. The indicator pointer did not appear to move even a fraction of the smallest division. Therefore, in determining the relative motion of bearing and shaft, the deflection error was neglected. The radial motion was eliminated by using precision ball bearings with zero internal clearance. The bearings were pre-loaded to further reduce the possibility of radial play.

The pillow blocks were of rigid construction so that there was no deflection in them. The driving motor was mounted separately and connected by a flexible coupling to isolate its vibration.

Four methods of measuring the motion of the bearings were considered: (1) dial gages, (2) optical microscopes, (3) air gages, and (4) electrical transformers. The electrical transformer method, while considered, was not utilized in this particular series of tests. It is, however, now being developed, and the results will be reported in a future paper.

Two different methods were used on each end of the bearing and all three methods are compared in the final results.

Dial Gage Method

The dial gage indicators had wide spaced graduations of 0.00005″, and the readings could be estimated to 0.00001″ with a possible reading error of plus or minus 0.00001″. These dial indicators were calibrated with Johanson blocks and proved to be excellent in the middle of their range, minus 0.0005″ to plus 0.001″, and did not require an instrument correction for linearity, hysteresis, or zero adjustment. Their total range is 0.003″. However, our interest was limited to a displacement of only 0.001″, which would correspond, for the bearing considered, to an eccentricity ratio of 0.5.

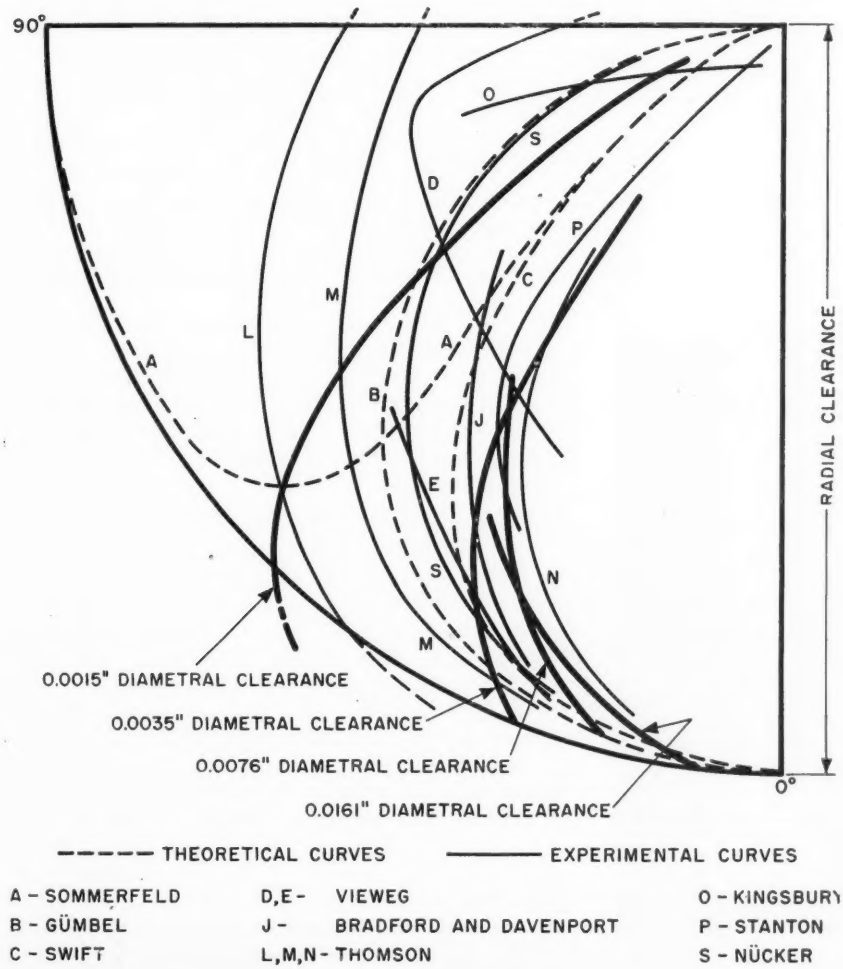

Figure 1. Comparison of results of other investigators.

Optical Microscope Method

Optical microscopes were also used for measuring attitude and eccentricity, by the use of two micrometer microscopes mounted 90° apart. The x axis microscope reads the y axis motion, and the y axis microscope reads the x axis motion. The microscope tube was equipped with coarse and fine adjustment screws for focusing. The objective had 43 magnification. The eyepiece used was a filar micrometer eyepiece of 12.5 magnification which is the type used for calibration of a microscope. The eyepiece contains a disc which is divided into 10 equal parts and a movable cross-hair. The cross-hair is moved by a mi-

crometer drum which is divided into 100 intervals. One complete revolution of the drum is equal to 1.00 mm. The cross-hair moves 1 division of the disc in one complete drum revolution. Calibration of the microscope indicated that one division of the drum was equivalent to 0.0000087". A reading of a fraction of a drum division was not recommended by the microscope manufacturer. The micrometer screw had backlash of about 2 divisions of the drum. This backlash could be subtracted by taking the zero reading in the same direction. However, when refocusing was necessary, this backlash may have introduced an error of about ±0.0000087". Two stage micrometer discs were mounted on the bearing, one on the x axis and the other on the y axis.

Air Gage Method

A fixture was made so that the dial indicators could be replaced with air gages. These gages were designed to produce 5000 X amplification, the greatest commercially available. The smallest scale division was graduated to 0.00005". The air gage cartridge is a precision variable orifice consisting of a spring urged plunger having a limited range of travel which controls the flow of air through an orifice. The variation of air flow is proportional to the plunger displacement, and is read directly as a flow change in the tubular type flow meter.

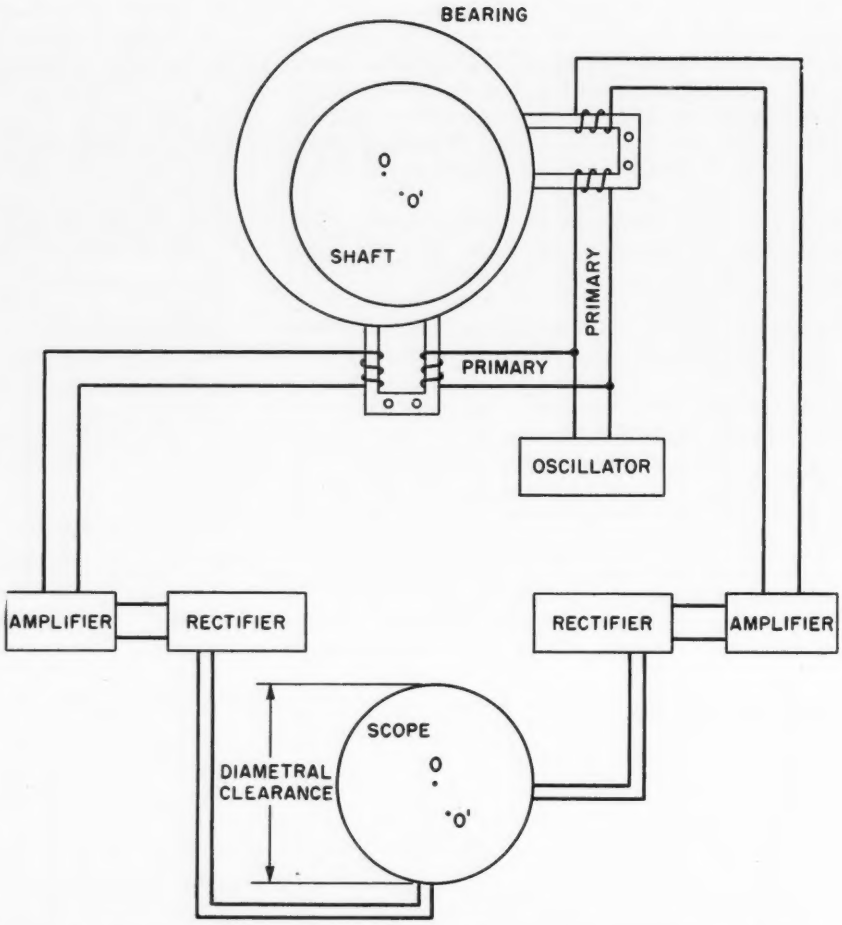

Figure 2. Instrumentation of method number four, for measuring eccentricity and attitude.

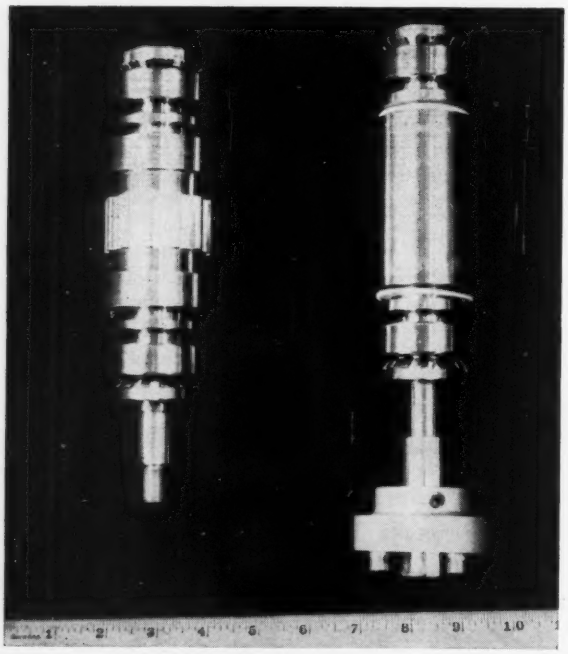

Figure 3. Plain and modified shaft.

Electrical Transformer Method

The electrical transformer method was considered as another possibility for measuring eccentricity. This was based on the use of small transformers or inductance coils mounted on the x and y axes of the bearing. A schematic drawing of the set-up is shown in Figure 2. This system has an advantage in that it is possible to observe the path of the shaft center on an oscilloscope and to actually take pictures of this path. Although this method was not used in the experiments reported in this paper, tests are now underway incorporating this means of measurement.

Figure 3 is a photograph showing the two shafts that were tested. The one on the right is a plain cylindrical shaft which was inserted in a plain journal bearing. Water was admitted by gravity at two points in the diverging region of the bearing clearance. The photograph of the shaft on the left in Figure 3 shows a modification composed of two plain journal sections placed on either side of a bearing made up of a series of Rayleigh steps. This was a

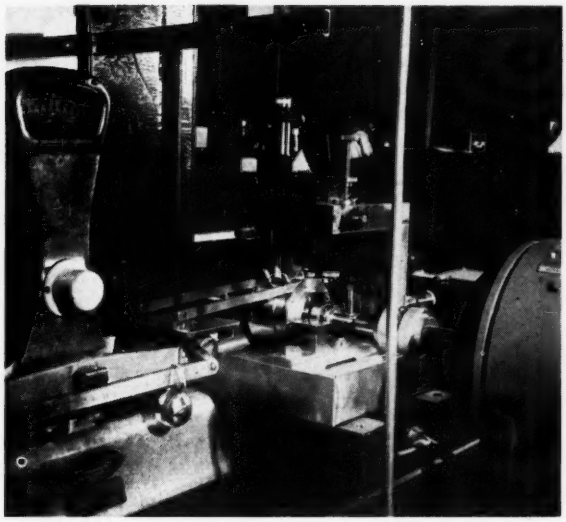

Figure 4. Apparatus using dial gages and microscopes.

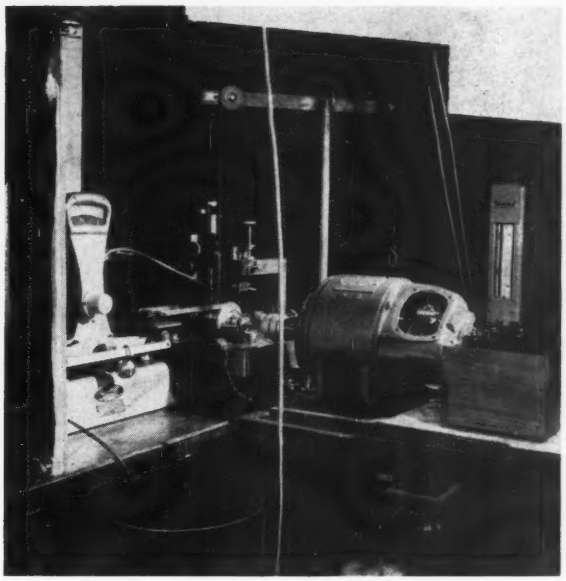

Figure 5. Apparatus using air gages and microscopes.

modification utilized in a study of journal bearing stability. This shaft operated in the same plain journal bearing as the previous one.

Figure 4 shows the apparatus using dial gages on the righthand side of the bearing, and microscopes on the left side of the bearing. Figure 5 shows the dial gages replaced by air gages, with its indicator on the right of the apparatus.

The bearing tested was 2-⅛″ in diameter by 2-¾″ long with a diametral clearance of 0.004″. Water was used as the lubricant. Load was applied in the vertical direction by a thin cable running over pulleys as shown in Figure 5. The variation in speed was from 1800 RPM to 2700 RPM, and the variation in applied load was from 5 lbs. to 60 lbs.

RESULTS

The results of measuring eccentricity locus clearly indicate that the three methods employed are in fairly close agreement. The air gages proved to have least divergence, and this method of measurement was considered to be most satisfactory. The dial gages proved to be next best. However, there appeared to be a lag and, during unloading, the results were not as reliable as they might have been. Since there was no hysteresis error in the measuring instruments, there probably was some hysteresis in the loading mechanism. Thus, when load was removed, eccentricity ratio and attitude angle may not have immediately assumed the position of equilibrium. This could have come from pulley friction in the loading arrangement.

It was very difficult to use microscopes due to their short focal length. The readings taken with the microscope should be considered the least reliable.

Very often during a run, a slight vibration was present so that the pointer in the case of the dial gage, and the float in the case of the air gage, oscillated approximately the equivalent of ± 0.000035″ (Table I). The amplitude of vibration had to be much greater before the air gage oscillated. When oscillation was present, the average reading was recorded. It should be pointed out, also, that a reading error of ± 0.000010″ may exist in the case of both the dial gage and the air gage.

Thus, we estimate that a total error of ± 0.000045″ may be present in the case of the dial and air gages. This is a very large percentage error when the readings are small, but becomes a comparatively small error when the readings

Table I

Errors Considered	Instruments		
	Dial Gages	Air Gages	Microscopes
1) Reading errors (human error) parallax	±0.00001″	±0.00001″	±0.0000174″
2) Equipment as cause of error			
a) Support deflection } Very Light Loads	negligible	negligible	negligible
b) Shaft deflection } Very Light Loads	negligible	negligible	negligible
c) Bearing deflection } Very Light Loads	negligible	negligible	negligible
d) Error introduced by taking avg. vibration reading	±0.000035″	±0.000035″	Impossible to take reading
3) Instrument error			
a) Linearity	No error*	No error†	
b) Hysteresis			
1. Friction			
2. Inertia	No error	No error	
3. Play			
c) Zero setting	No error	No error	During refocussing 0.0000174″
Smallest scale division	0.00005″	0.00005″	0.0000087″

*Between −0.0005″ to +0.001″

†Based on manufacturers data the instrument was calibrated at two points amplification, and limit marks were set. Linearity was assumed.

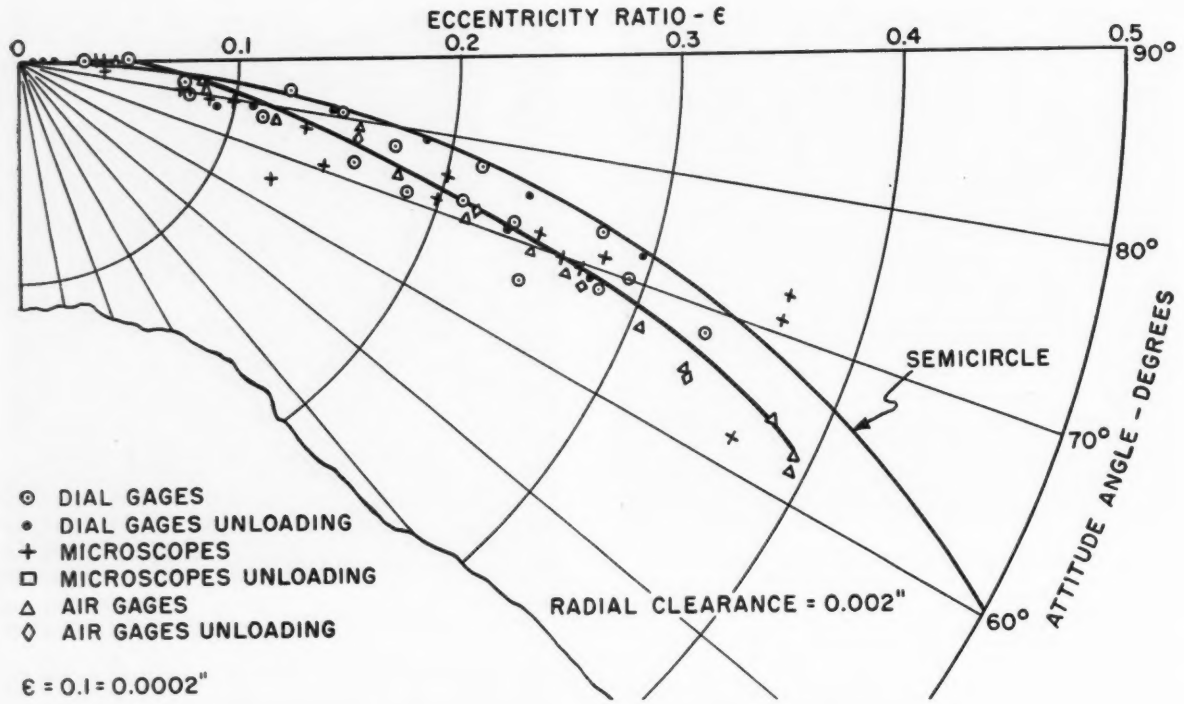

Figure 6. Eccentricity locus of plain journal bearing comparing three methods of measurement.

are large, e.g. when the reading is 0.000045", the error may be as much as 100%; when the reading is 0.0009", however, the error may be 5% or less.

A study of Figure 6 will show that the eccentricity locus is within the experimental error (Refer to Table II). The displacement is initially horizontal from the origin, where the attitude angle is 90°, up to a point of approximately ecentricity ratio equal to 0.05; then there appears to be a departure from this horizontal shift, and the locus curves down in the expected manner. It appears, therefore, that for very light loads producing extremely small eccentricity ratios, the motion of the shaft is horizontal and perpendicular to the direction of the applied load much as predicted in the classical theory by Sommerfeld. Perhaps the negative pressures in the crown of the bearing (the unloaded side) are contributing equally to the load carrying capacity of the bearing as the positive

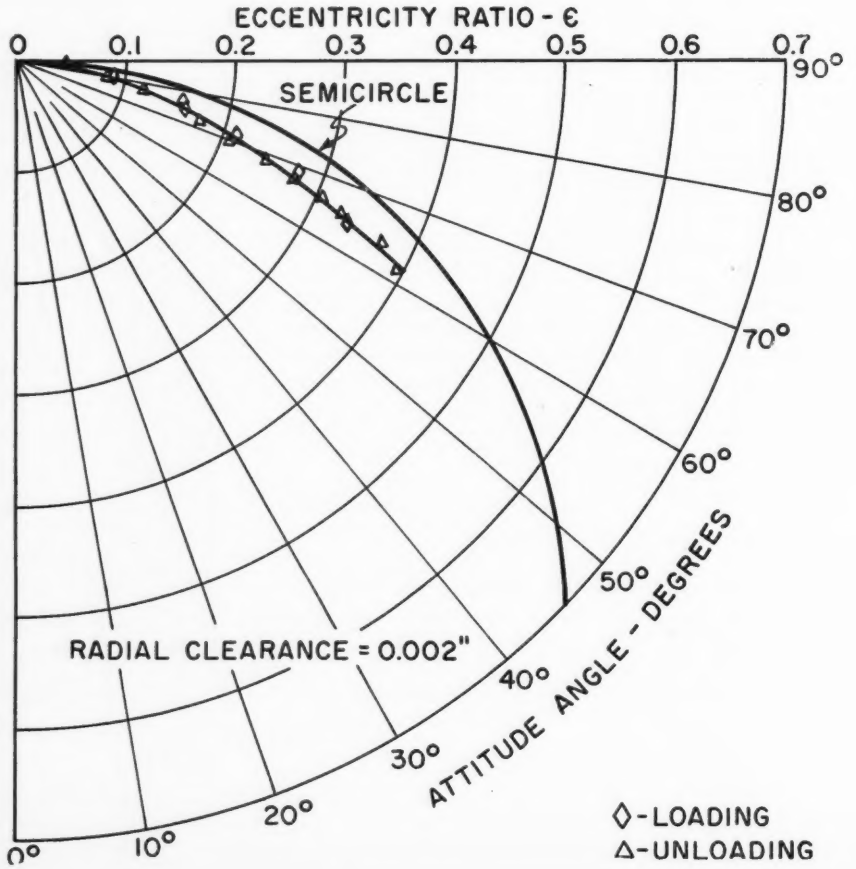

Figure 7. Eccentricity locus of plain journal bearing employing air gages for measurement.

pressures in the loaded side. As operating conditions become more severe, it is generally agreed that the negative pressures in the crown of the bearing can no longer match the positive pressures under the load and, consequently, the locus of the eccentricity path curves downward in roughly a semi-circular pattern. The results in Figure 6 show that this is one of the few times that sufficient accuracy has been available in the measurements of eccentricity ratio to indicate this horizontal shift of the journal in the bearing at exceedingly light loads. Figure 7 shows a replot of the data using only the experimental values obtained from the air gages, since they proved to be the most consistent. The eccentricity locus is approximately that of a semi-circle, but sufficiently different, so that if high accuracy were required in determining attitudes and eccentricities of a plain shaft and a plain bearing, the true eccentricity locus would be required. Figure 8 shows the eccentricity locus for the modified shaft in which no initial horizontal motion was observed. The eccentricity locus close to the origin has a distinct and measurable angle. For higher values of eccentricity ratio, the deviation from a semi-circle is distinct and marked. It was necessary to obtain this locus as part of a bearing stability analysis. Since both bearings had a diametral clearance of 0.004", the total radial motion of the shaft with respect to the bearing is only 0.001" for a corresponding eccentricity ratio of 0.5.

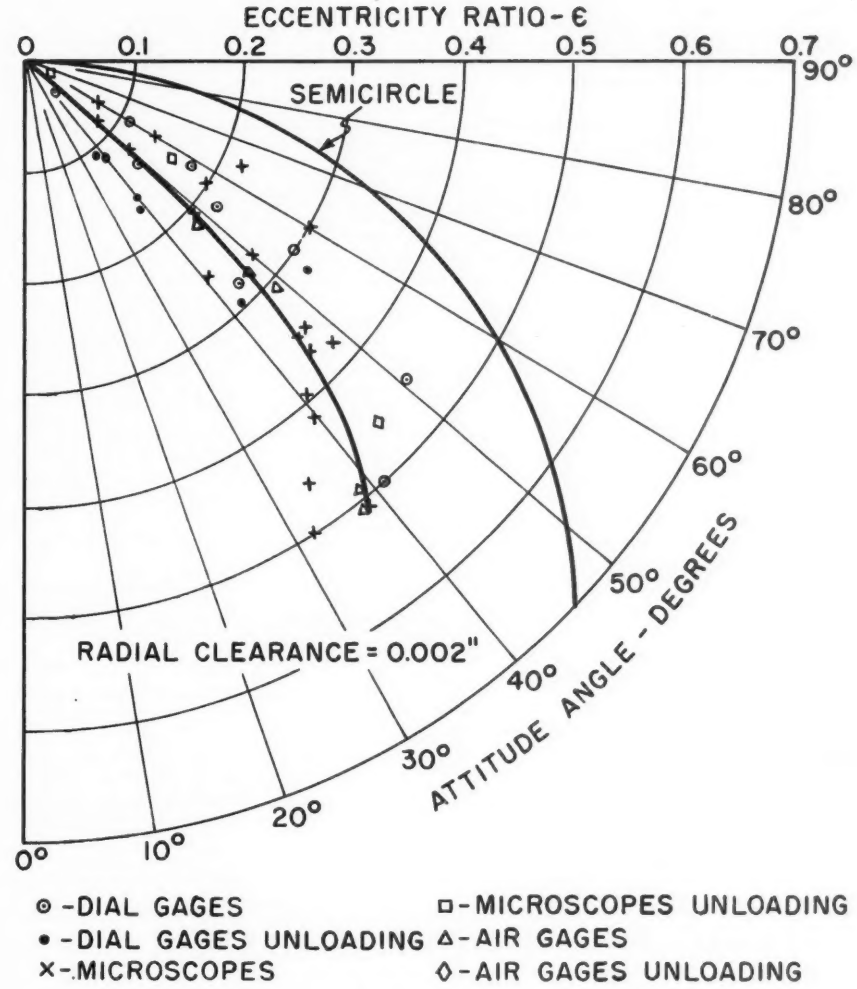

Figure 8. Eccentricity locus of modified journal bearing comparing three methods of measurement.

Table II

Load, lbs.	Eccentricity Ratios: Calculated* Needs plus Karelitz Method	Air Gages Loading Test Results	Air Gages Unloading Test Results
5	0.042	0.045	
10	0.082	0.081	0.086
15	0.120	0.117	
20	0.160	0.153	0.159
25	0.190	0.177	
30	0.220	0.211	0.216
35	0.251	0.245	
40	0.281	0.274	0.273
45	0.310	0.305	
50	0.341	0.330	0.333
55	0.370	0.375	
60	0.400	0.392	

*Method of calculation outlined in "Historical Development of Hydrodynamic Lubrication," Fundamentals of Friction & Lubrication in Engineering, ASLE, 1954, pp. 10-13.

CONCLUSIONS

It is quite apparent from the results that there is very good correlation between the three methods employed. The air gages appeared to be the most reliable, and their use was considered to be most satisfactory. The potential value of the electrical transformer method for measuring attitude and eccentricity is now being investigated. The experimental investigations described in this paper are part of the work performed by Mr. B. Sternlicht in the preparation of his doctoral thesis in the Dept. of Mechanical Engineering at Columbia University.

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ACKNOWLEDGEMENTS. We gratefully acknowledge the aid and encouragement of Prof. G. F. Boeker of the City College of New York and Columbia University, and of Prof. L. J. Hayner of the Physics Dept. at Columbia University. The facilities for performing these experiments were largely provided through the financial assistance of the Eugene Higgins Trust. We should also like to thank the General Electric Company for extending many courtesies and some physical aid.

Foreign Lubrication Abstracts

(This is the twelfth in a series of abstracts of translations of Foreign articles on lubrication, by Henry Brutcher. Copies of the full translations are available, at the indicated prices, by writing Mr. Brutcher at P. O. Box 157, Altadena, Calif.)

A New Piston Ring Material, by E. A. Sukhodol'skaya, "Liteinoe Proizvodstvo," Vol. 2, February 1953, pp. 21-23; 10 figs., 2 tables, 2,100 words. Importance of graphite structure for high-grade piston rings with good elasticity and wear resistance. Theoretical consideration of the various functions of graphite in piston ring iron. Cast irons studied: (1) ordinary gray iron with up to 5% ferrite; (2) Cr, Ni, Mo, W, and Cu alloyed cast irons; (3) nodular iron. Preparation of specimen rings for tests. Results obtained in laboratory wear tests and in actual service in automobiles (Figs. 7-9). Procedure for testing the rings for elasticity; results (Table II & Fig. 10). Particulars on the suitability of nodular iron for use in piston rings. (Order No. 3241, price $4.20)

X-Ray Study of Structure of Chips Obtained in Metal Cutting, by S. I. Gubkin & L. T. Mendeleev, "Doklady Akademii Nauk SSSR," Vol. 95, No. 1, 1954, pp. 73-74; 1 fig., 900 words. Experimental evidence that metal cutting is based on a mechanism of deformation that obeys the same laws as the deformation mechanism for rolling, forging, etc. Study of chip structure of copper, aluminum, brass, and 0.45% C steel by the Debye powder method. Experimental procedure and results (Figs. la-ld). Conclusions. (Order No. 3311, price $2.15)

Radioactive Wear Measurements, an Approach to Rapid Routine Testing for Tool Performance, by O. Hake, "Industrie Anzeiger," Vol. 77, No. 45, 1955, pp. 627-630; 15 figs., 2,400 words. Description of a method based on gamma-ray measurements of the quantity of activated tool material taken away by the chips in machining operations. Testing arrangement (Figs. 3-5) and procedure; testing times selected. Data on machining (lathe) a semi-hard carbon steel, using tools tipped with five different cemented carbide compositions and an HS tool. Conclusions: proposed method quickly supplies relative and absolute tool wear data for the plotting of tool-life curves. (Order No. 3584, price $4.80)

Influence of Tempering upon Hardness Retention of Electro-sparked Surface Layers, by G. P. Ivanov et al, "Metallovedenie I Obrabotka Metallov," Vol. 1, No. 4, 1955, pp. 48-51; 4 figs., 1,300 words. Investigation of stability at elevated temperatures of surface zones produced on steel by electro-spark treating under more severe conditions than hitherto applied: namely, 0.3 kw, 15 v, 20 amps; and 1.25 kw, 32 v, 39 amps; capacitance: 600 mf per electrode. Basis material: normalized 0.45% carbon steel. Electrode materials studied: cemented carbides (79% WC, 15 TiC, 6 Co); ferrochromium; ferroboron; tungsten metal; chromium metal, technically pure and also with 4% nitrogen. Tempering temperatures: 300-800° C. (570-1470° F.). Results of microhardness measurements (Figs. 1-4). Conclusions as to best electrode materials for electro-sparking components exposed to abrasive wear at high temperatures, such as gas turbine blades, extrusion dies, flue-gas pump impellers, etc. (Order No. 3735, price $3.45)

Calorizing of Gas-Turbine Blades of Austenitic Steel, by V. I. Prosvirin et

(Continued on p. 231)

The Role of Sulfate-Reducing Bacteria in the Deterioration of Cutting Emulsions

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Bacterial growth in cutting emulsions has been a source of considerable trouble and expense to the metal cutting industry for many years. Aside from the industrial hygiene problems created by contaminated oils, emulsions tend to break, foul odors are produced, and the emulsions must be replaced, resulting in a loss of production. Though bacteria are suspected of playing a major role, little is known about the specific organisms that are responsible for the emulsion instability, the odor, or the discoloration associated with spoilage.

In recent years, reports of bacteria in emulsions have dealt with organisms that prefer oxygen for growth (Lee and Chandler, 1941; Duffett *et al.*, 1943; Pivnick and Fabian, 1954; and Bennett and Wheeler, 1955). These investigators have reported aerobic bacterial counts in emulsions that were frequently as high as 30 to 40 million organisms per ml.; yet in no instance was characteristic spoilage noted, even after many months of observations.

Bacteriological studies of emulsion oils have usually employed some method of aeration by bubbling, circulation, or agitation in an attempt to duplicate industrial conditions as nearly as possible. Actual industrial spoilage of emulsions usually occurs on week-ends when the equipment is not in operation, and the emulsion is allowed to stand in the reservoir. During this period an oil cap forms on the surface, and the aerobic organisms deplete the oxygen content of the emulsion. Thus, in actual practice, spoilage takes place in the absence of oxygen and agitation.

Liberthson (1945) reported that typical spoilage of emulsions could be produced experimentally only under anaerobic conditions. Aerobic conditions did not produce the characteristics of a spoiled emulsion, and in fact, bubbling compressed air through deteriorated emulsions restored their original color and stability to a satisfactory degree. He suspected that anaerobic sulfate-reducing organisms might produce this deterioration of emulsions, but neither Liberthson nor other investigators have pursued this observation.

Since the anaerobic sulfate-reducing organisms have been implicated, an attempt was made to isolate these organisms from used industrial emulsions. This preliminary report proves that sulfate-reducing bacteria are present in emulsion oils, and that experimental spoilage of the emulsion can be produced by these organisms.

EXPERIMENTAL PROCEDURE

Thirty-three samples of used emulsion were collected in sterile containers from various industries in the Southwest. Five ml. quantities of these samples were promptly inoculated into duplicate glass stoppered flasks of sterile medium with the following composition:

K_2HPO_4	.2 gm.
$MgSO_4.7H_2O$	.2 gm.
$(NH_4)_2SO_4$	1.0 gm.
Na_2SO_3	.1 gm.
Ca lactate	3.5 gm.
Ascorbic Acid	.1 gm.
$FeSO_4(NH_4)_2SO_3.6H_2O$	.1 gm.
Peptone	1.0 gm.
Yeast Extract	1.0 gm.

in 1000.0 ml. of tap water.

All cultures were incubated at room temperature and observed for production of iron and hydrogen sulfides.

Sulfate-reducing bacteria were isolated from 28 of the spoiled emulsions, but only one culture was selected for additional study. The purification procedure reported by Butlin *et al.* (1949) for sulfate-reducing organisms was employed in an attempt to obtain a pure culture. This procedure has not produced successful results as yet, but further attempts are being made to obtain pure cultures.

Experimental deterioration of cutting emulsions was produced, however, by inoculating the mixed culture into the following media:

Medium 2

K_2HPO_4	.2 gm.
$MgSO_4.7H_2O$	.2 gm.
$(NH_4)_2SO_4$	1.0 gm.
Na_2SO_3	.1 gm.
$FeSO_4(NH_4)_2SO_3.6H_2O$	.1 gm.

dissolved in 1000.0 ml. of a 1-25 dilution of commercial cutting emulsion in tap water.

Medium 3

Same as Medium 2, plus 10.0 grams of iron filings.

RESULTS & DISCUSSION

Fifteen different commercial cutting emulsions were represented in 33 samples studied. Only one product represented by 3 samples was consistently free of sulfate-reducing bacteria. These organisms appear to be present in most used emulsions, and the manufacturers are either unaware of their relationship to spoilage, or they have not been able to develop suitable inhibitors for them.

The viability of sulfate-reducing organisms in emulsions is an important factor in determining whether or not they are part of the indigenous flora of these lubricants. Organisms that are commonly found growing for prolonged periods of time in a particular environment are usually

considered to be part of the indigenous flora of that environment. This fact has been demonstrated before by workers who have found that different species of Pseudomonads are frequently found growing in emulsions. These organisms are considered to be part of the indigenous flora of emulsion oils. Other organisms such as Staphylococci do not survive because they are not part of the normal flora and are present in the emulsion only by chance. A sample of spoiled emulsion collected nine months prior to this study was examined for the presence of sulfate-reducing organisms. A duplicate set of Medium 1 was inoculated with 5.0 ml. quantities of spoiled emulsion. The presence of sulfate-reducing bacteria was noted by the production of iron and hydrogen sulfides after four days incubation at room temperature. This shows that sulfate-reducing bacteria remain viable in spoiled emulsions for considerable periods of time, and gives additional evidence that they might be regarded as part of the natural bacterial flora of these emulsions.

An additional factor of importance in determining if sulfate-reducing bacteria are part of the indigenous flora of emulsions is concerned with the organism's capability to grow in a medium in which the coolant is the sole source of carbon. If growth occurs, it would indicate that these organisms are capable of utilizing hydrocarbons as a sole source of carbon for the synthesis of cellular material. For this type of study a pure culture of organisms is preferable.

Cultures of sulfate-reducing organisms isolated in nature are often contaminated with heterotrophic bacteria. Purification of these cultures is very difficult and often disappointing. When the purity of the culture used in producing experimental spoilage of emulsion oil in this investigation was checked by routine plating procedures, an unidentified heterotrophic organism was isolated. The organism is a short, gram-negative, motile, facultative anaerobic bacillus, which produces cream colored colonies on nutrient agar. Unlike sulfate-reducing bacteria, this organism produces turbidity in Medium 1 and does not form hydrogen sulfide. Evidence of contamination was noted in all cultures of sulfate-reducing bacteria isolated from emulsions. Additional cultures of sulfate-reducing bacteria were obtained from another laboratory. All cultures were found to be contaminated with heterotrophic bacteria, capable of growing under aerobic conditions.

Postgate (1953) also described a contaminant of sulfate-reducing bacteria cultures. This organism was an obligate anaerobic, gram-negative, often paired, non-motile rod, which formed yellow tinted colonies. Growth was improved by addition of filtrates from pure cultures of *Desulphovibrio*. This observation strongly suggests that there may be some nutritional interdependence between sulfate-reducing bacteria and other forms of bacteria.

Since pure cultures of sulfate-reducing bacteria could not be obtained, it was decided to determine what effect the impure culture had on Medium 2 in which the emulsion is the sole source of carbon. Triplicate sets of Medium 2 were inoculated with 5.0 ml. quantities of the sulfate-reducing culture and incubated at room temperature. The emulsion turned blue and then dark gray, and a black film formed on the upper walls of the container within 72 hours.

Rubenchik (1946) believes that silicic acid rises in the form of a sol which is deposited on the walls of the container where it becomes a gel and is transformed into

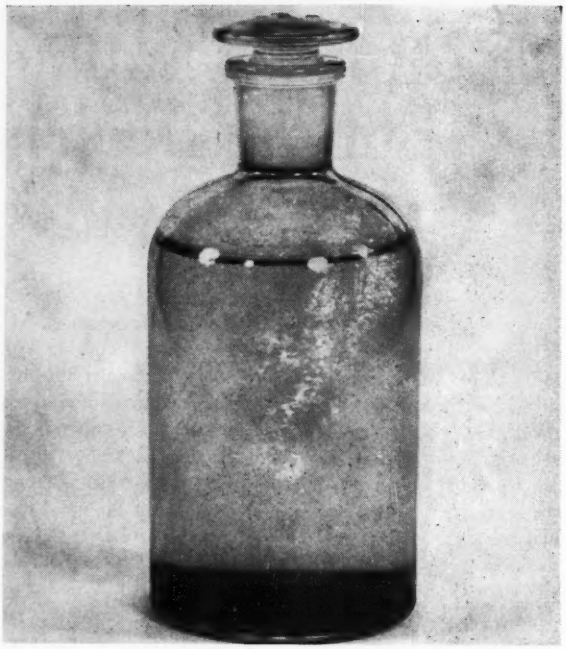

Figure 1. Culture of sulfate-reducing bacteria isolated from emulsion oil.

a thin membrane. This membrane is stained black as a result of iron sulfide formation.

In our experiments, iron sulfide precipitate was also present in the bottom of the flask. Slight breaking of the emulsion and slight odor, typical of spoiled emulsions, was produced. The absence of strong odor was probably due to the conversion of the hydrogen sulfide into iron sulfide. Seven days later an additional triplicate set of Medium 2 was inoculated with 5.0 ml. quantities of the first set. Production of iron sulfide was not as abundant in the second set as in the first. A third set of subcultures has not been attempted due to the poor growth in the second set.

The contaminating heterotrophic organisms were isolated in pure culture and inoculated into Medium 2. After many weeks of observation no visible change was produced. Any change, therefore, in the contaminated culture could be assumed to be due to the sulfate-reducing organisms, or to a symbiotic relationship between both organisms.

The iron filings found in industrial emulsions might be important in the nutrition of sulfate-reducing bacteria and deterioration of emulsions. Butlin *et al.* (1949) reported that sulfate-reducing bacteria do not grow in the absence of iron and hydrogen. Butlin and Adams (1947) showed that mild steel acted as a hydrogen donor due to the formation of an electrolytic film of hydrogen at its surface contact with water. Stephenson and Strickland (1931) showed that a strain of sulfate-reducing organisms utilized the gaseous hydrogen, and that sulfate reduction proceeded quantitatively according to the equation:

$$SO_4'' + 4H_2 \rightarrow S'' + 4H_2O$$

Triplicate sets of Medium 3 were inoculated with 5.0 ml. quantities of the sulfate-reducing culture. A dark blue layer of iron sulfide appeared over the iron filings after 24 hours incubation at room temperature. The medium turned dark gray throughout after 48 hours. Metabolic activity,

as indicated by iron sulfide formation, was greater in the presence of iron filings than in their absence. Subcultures were made after twelve days incubation from the first set into a second set of Medium 3. The emulsion turned light gray within 48 hours but deterioration did not progress further. Nine days later, a third set of subcultures was made from the second set. Growth in the third set has been very unsatisfactory.

There are several possible explanations for these observations. A series of subcultivations may have been impossible due to the particular emulsion used, although another emulsion was studied and the same results were obtained.

Another explanation could be that as the sulfate-reducing bacteria are passed through a series of emulsions, an increasingly longer lag period accompanies each transfer. Hence, the initial lag period (before the sulfate-reducing organisms begin to grow) may be several weeks in the case of third and fourth subcultures. Additional study of this possibility is underway.

These results also indicate that there may be a factor(s) necessary for growth of sulfate-reducing organisms that is not present in either medium. An infinite number of subcultures could be possible if all factors necessary for growth were present. Growth in one or two subcultures could indicate a "carry over effect". Some essential unknown factor(s) is carried over from the complete medium, and this factor(s) is gradually diluted or utilized until growth is impossible.

The abundance of reports on the presence of large numbers of heterotrophic microorganisms in cutting emulsions cannot be ignored. These organisms could possibly have some part in a nutritional inter-relationship with sulfate-reducing bacteria. Due to their shorter initial lag period and generation time, they must precede the growth of sulfate-reducing bacteria.

Heterotrophic microorganisms may also produce cer- conditions that would initiate growth of the sulfate-reducing organisms. Heterotrophic microorganisms lower the oxygen tension of the emulsion and produce anaerobic

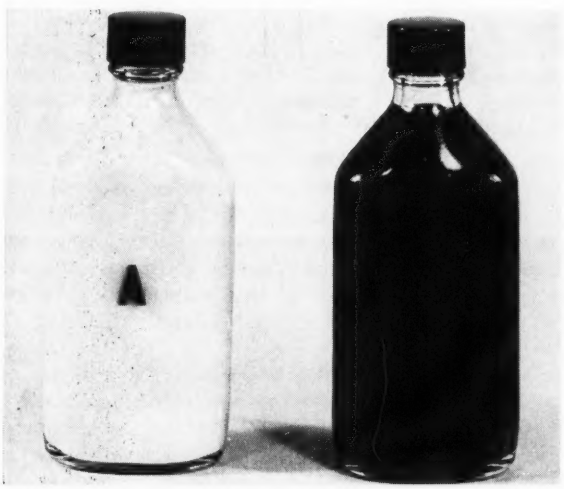

Figure 2. Complete spoilage of emulsion oil by sulfate-reducing bacteria. A: fresh emulsion; B: spoiled emulsion produced by growth of sulfate-reducing bacteria. Inorganic salts and organic material added to bring about optimum growth.

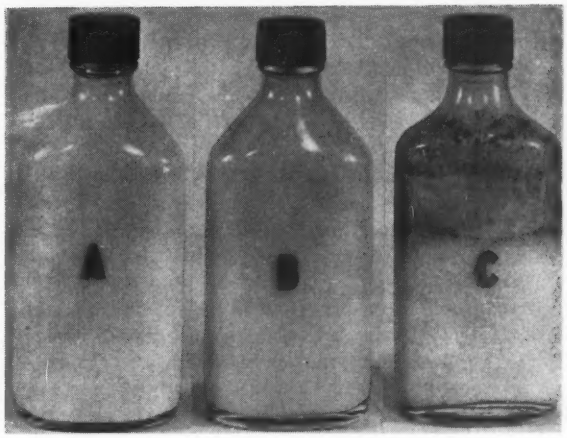

Figure 3. Effect of aerobic and anaerobic bacterial growth on emulsion oils. A: fresh emulsion; B: aerobic growth for 266 days (emulsion is slightly brown in color); C: anaerobic growth of sulfate-reducing bacteria for 15 days (emulsion gray in color, with iron sulfide precipitate on walls).

conditions. The flasks of Medium 2 and 3 were capped and filled to the top so that very little air was present. Reduction of the oxygen tension may favor growth of sulfate-reducing bacteria, but it does not appear to be the factor(s) involved.

Initial heterotrophic growth in emulsions results in a decrease in nitrogen content of the emulsion (Bennett and Rappoport, unpublished data). Rubenchik (1946) reported that denitrifying bacteria have a favorable influence on the growth of sulfate-reducing bacteria in the presence of nitrates.

Kupzis (1928) observed that both living and dead cultures of *Pseudomonas fluorescens* increased the reduction of sulfate by sulfate-reducers.

Heterotrophic microorganisms may also produce certain compounds that are essential or stimulatory for growth of sulfate-reducing bacteria.

The growth of sulfate-reducing organisms can be stimulated by the production of small amounts of hydrogen sulfide. Kallio and Porter (1950) have reported the formation of hydrogen sulfide by heterotrophic organisms from sulfur-containing amino acids.

The amino acids, cysteine, ornithine, serine, and isoleucine, have a growth-promoting effect on sulfate-reducing bacteria. Cysteine is the most important compound, because, in its absence, the other amino-acids were not active (Postgate, 1951). Grossman and Postgate (1953) showed that cysteine could be replaced by Na_2S, indicating that the compound may function through its reducing properties and not as a nutrient. It is conceivable that heterotrophic organisms could supply these amino acids to the sulfate-reducing organisms in addition to compounds with reducing properties.

Other stimulatory factors, such as polypeptides, could be produced by heterotrophic bacteria. Postgate (1951) has shown that these compounds stimulate the growth of sulfate-reducing bacteria.

Heterotrophic organisms could function in the conversion of the sulfonates used in the emulsifiers to a form that can be reduced by the sulfate-reducing organisms. Sulfate-reducing bacteria are capable of reducing sulfates,

sulfites, thiosulfates, tetrathionates, and metabisulfites to sulfides (Postgate, 1951). It must be remembered that Medium 2 and 3 contain sulfate. This fact indicates that the production of sulfate may not be the most important contribution made by heterotrophic organisms.

Liberthson (1945) discussed a possible role of the heterotrophic organisms in producing conditions optimum for growth of sulfate-reducing organisms in cutting emulsions. He points out that carbon dioxide is indispensable for the growth of sulfate-reducing organisms. The spoiled emulsion may acquire a carbon dioxide content through the decomposition of organic matter in the accumulated debris and, also, may become secondarily contaminated with one or more organisms capable of oxidizing hydrocarbons to form carbon dioxide and water. The symbiotic function of such hydrocarbon consuming organisms in the presence of sulfate-reducing organisms might conceivably be adequate to supply an environment with a carbon dioxide concentration sufficient for growth of sulfate-reducing organisms.

It is now established that sulfate-reducing organisms are present in emulsion oils and play a major role in producing the characteristics of a spoiled emulsion. It would be interesting to know how these organisms are introduced into the emulsion. Guynes and Bennett (unpublished data) found that the oil as sold by the manufacturer does not contain sulfate-reducing bacteria. The manufacturer markets a product which is free of bacteria, but the user contaminates it in many interesting and deplorable ways. Westveer (1951) reported that contaminated water used to make up the emulsion is one of the contributing sources of bacteria found in emulsions. This water may come from a river or well located near the industry. The open circulation systems are contaminated by exposure to air, contaminated metal parts, workers hands, urine, feces, sputum, dirt, and refuse thrown into the emulsions by the workers. In regards to the sulfate-reducing organisms, one of the most logical sources of these organisms would be the water used in making the emulsion. It would be wise for industry to be more particular in its source of water.

Possibly the conditions necessary for spoilage are produced by several phases of use and inactivity over a prolonged period of time. Sulfate-reducing organisms and aerobic bacteria are introduced into the emulsion. The aerobic organisms begin to reproduce during periods of activity. These organisms continue to grow during periods of inactivity and result in the depletion of the oxygen content of the emulsion. The sulfate-reducing organisms begin to grow in the resulting anaerobic environment. Circulation is started during the work week. The increased population of sulfate-reducing organisms is held static or possibly reduced slightly by aerobic conditions. This period of activity is followed by a period of week-end inactivity resulting in additional growth of the sulfate-reducing bacteria. Suddenly, after a variable period of time, depending on such factors as the susceptibility of the formulation to bacterial attack and the size of the original inoculum of sulfate-reducing organisms, spoilage occurs. The spoiled emulsion is discarded, and the system is refilled with fresh emulsion. What follows may be called "the dissatisfied cutting oil user syndrome". The initial concentration of sulfate-reducing bacteria in the new emulsion is high due to residual contamination from the circulation system. Within a short time the new emulsion spoils. Often the user will blame the manufacturer of the emulsion and will change to another product. Due to a different formulation and inhibitor, the new product will function satisfactorily for a variable period of time, while all of the microorganisms are adjusting to the new substrate. Invariably, however, the emulsion will spoil and the cycle will be repeated.

Table I

Isolation of Sulfate-Reducing Bacteria from Emulsion Oils

Commercial Emulsion	No. Samples Studied	No. Samples Containing Sulfate-Reducing Bacteria
A	1	1
B	1	1
C	2	2
D	2	2
E	2	2
F	3	0
G	2	2
H	3	3
I	5	4
J	1	0
K	3	3
L	1	1
M	4	4
N	1	1
O	2	1

In order to control the bacterial deterioration of emulsion oils, some industries employ periodic pasteurization of the emulsion in addition to the use of bacterial inhibitors. Weirich (1943) reported that heating emulsions to temperatures of 60 to 71° C. for thirty minutes is ample for killing the heterotrophic bacteria present in the emulsion, but he points out that there have been many instances where heat sterilizers have been installed and have failed entirely because of careless operation. The reduction of heterotrophic microorganisms can be accomplished by this method, but the procedure does not seem adequate for preventing deterioration in many cases. Rubenchik (1946) reported the isolation of sulfate-reducing bacteria from an environment with a consistent temperature between 50 to 60°C. He also points out that the conditions necessary for spore formation with spore-forming strains of sulfate-reducing bacteria are established when the cells are heated to 80° C. for twenty minutes. There are many other reports in the literature that could be cited dealing with the thermophilic properties of sulfate-reducing organisms. It is unlikely, therefore, that pasteurization of the emulsions has any significant effect upon sulfate-reducing bacteria.

The most important effect of these observations is related to previous reports on the use of bacterial inhibitors in emulsions. All of the previously reported inhibitor studies were carried out under aerobic conditions and based upon the inhibition of heterotrophic bacteria. None involves the inhibition of sulfate-reducing organisms (Lee and Chandler, 1941; Westveer, 1951; Pivnick and Fabian, 1953; and Wheeler and Bennett, 1956). None of the inhibitors reported to be effective have been reported active against sulfate-reducing bacteria. Additional studies need to be undertaken to determine the effect of inhibition of heterotrophic bacteria on the growth of sulfate-reducing organisms. Inhibitors will have to be studied to determine whether or not they are effective against sulfate-reducing organisms. It will be interesting to find out how rapidly these organisms can develop resistance to inhibitors em-

ployed against them.

This report indicates that one of the most important methods for retarding the spoilage of emulsions involves the use of forced aeration of the emulsion reservoir. Liberthson (1945) reported that aeration stopped the deterioration process and freshened the partially spoiled emulsion. This practice not only eliminates the production of unpleasant odors but possibly kills the anaerobic sulfate-reducing organisms. Bennett (unpublished data), employing constant aeration of open jars of uninhibited emulsion for more than nine months, could not recover sulfate-reducing organisms even though they were present in the original inoculum used in the jars.

Some companies have already adopted the system of constant, forced aeration of their reservoirs. Aeration should become a common practice throughout industry, acting as an adjuvant in conjunction with chemical inhibitors used to prolong the "life" of the emulsion.

This report indicates that considerable work still needs to be done in order to make emulsion oils safer and less troublesome lubricants.

SUMMARY

Sulfate-reducing bacteria were found in samples of used industrial emulsions. These organisms were shown to be capable of spoiling emulsions under experimental conditions, although additional factors are needed for continued spoilage of a series of emulsions. The practical aspects of these observations are discussed.

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Lubrication Abstracts

(Compiled by the ASLE Abstracts Sub-Committees.)

"Blisters in Babbitt," by J. C. Helbling, *Steel, Vol. 139*, No. 15, October 8, 1956, pp. 95-98. The formation of babbitt blisters on thrust-bearing shoes due to hydrogen pressure at the steel-babbitt interface is discussed. The diffusion of hydrogen contained within the steel is explained. Tests to determine the allowable hydrogen content of steel in order to prevent such blisters are described. Heat-treating times and temperatures are presented for the reduction of hydrogen from 5.5 ppm to 1.1 ppm for the case of a 6" thick plate. *(Abstracter: H. N. Kaufman)*

"Card System Makes Lubrication a Cinch," by G. C. Close, *Mill & Factory, Vol. 59*, No. 5, November 1956, pp. 134-135. Results of a survey of lubrication requirements for approximately 300 machines in an aviation plant are given and the action taken following the survey is described. A card file system is set up with a separate card, stating frequency and other requirements for every point of application, for each machine. Each machine must be lubricated as required on the card. The oiler initials the card on completion of the job and returns it to the superintendent's office. Installation of the system reduces inventory of plant lubricants by 2/3 and effects substantial reduction in labor costs. *(Abstracter: E. S. Reynolds)*

"Centralized Coolant Filtration Cuts Tool Cost, Increases Production 15%," by H. D. Klitgord, *Amer. Mach., Vol. 100*, No. 14, July 2, 1956, pp. 88-91. A study of filtration methods for coolant on turret lathes and automatic machines used in instrument manufacturing is described, the object being to increase tool life by removing metal "fines" from the lubricant. The study results in the choice of pressure-filter system which removes particles as small as 5-10μ in. at a practical flow rate, from lubricant for 100 machines. In addition to a 30% increase in tool life, increased production, decreased maintenance costs, and other advantages result from the installation. It is estimated that the cost of the filter system pays for itself in one year of two-shift operation. *(Abstracter: E. S. Reynolds)*

"Effect of Lubricant on Pitting Failure of Ball Bearings," by F. T. Barwell & D. Scott, *Engineering, Vol. 182*, No. 4713, July 6, 1956, pp. 9-12. An adaptation of the Boerlage 4-ball test machine is used to evaluate the effect of lubricants on pitting failure of ball bearings. Test results are given for a number of lubricating and hydraulic fluids. A metallurgical investigation of the failures is also discussed. *(Abstracter: H. Connors)*

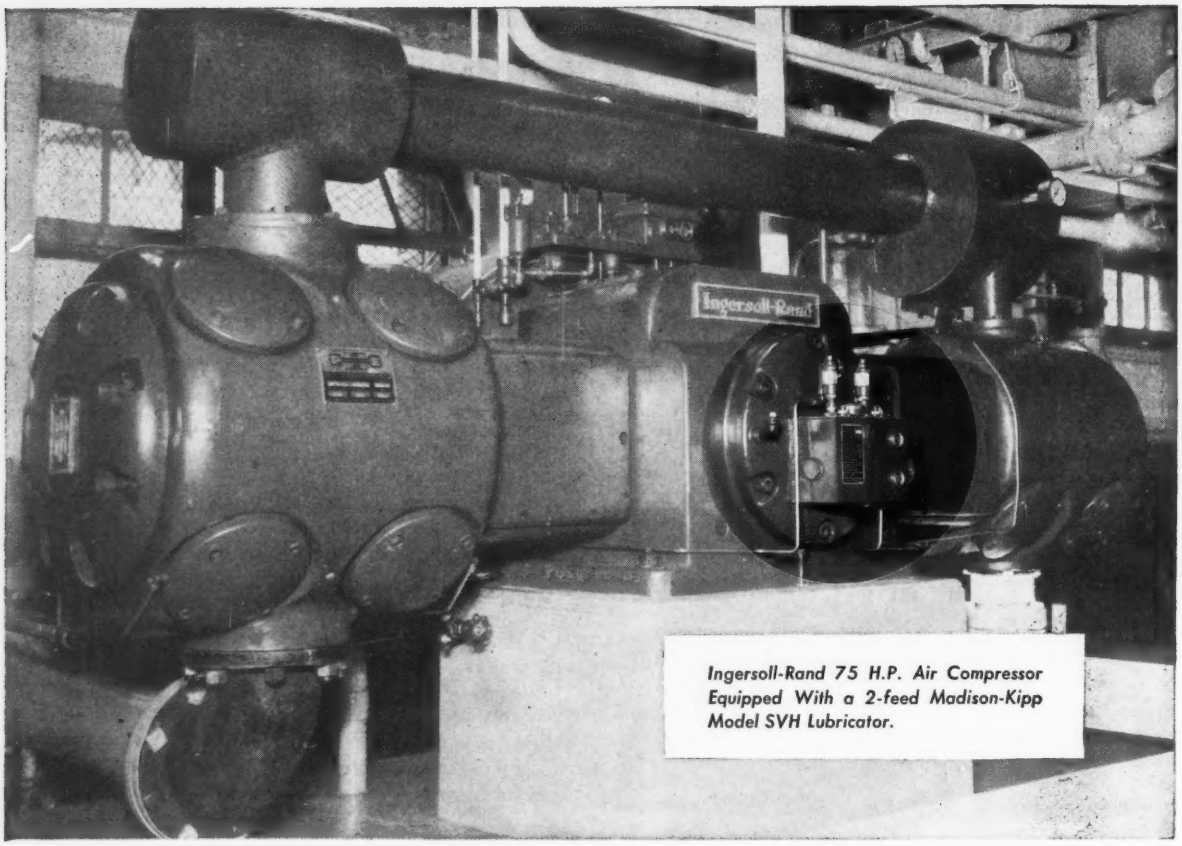
"Improving Cutting Oils," *Petroleum, Vol. 19*, No. 9, September 1956, pp. 319 & 332. Radioactive cutting tools are used to evaluate the relationship between cutting oils and tool life. Preparation of radioactive tool bits is outlined and test procedure is discussed. *(Abstracter: W. J. Wojtowicz)*

"Lubrication in Drawing," by E. D. Viers, *Steel, Vol. 139*, No. 2, July 9, 1956, pp 86-89. A variety of failures in draw-press work are discussed. Factors which affect lubricant selection are presented.

No. 3, July 16, 1956, pp. 148-150. A review of raw materials used in draw die lubricants is given. Typical methods of lubricant application are presented.

No. 4, July 23, 1956, pp. 94-96 & 98. Essential properties of drawing lubricants are given in order of their importance. Illustrated examples appear in all articles. *(Abstracter: W. J. Wojtowicz)*

"Lubrication of Textile Spindle Bearing," by J. P. Vidosic & R. D. Cheverton, *Textile Research Journal, Vol. 26*, No. 8, August 1956, pp. 622-629. An experimental study to determine the operating characteristics of the plain-bearing spindle is described, having the objective of reduction in the large power consumption in high-speed textile spindles. Data are presented which show the influence of speed, package size, oil viscosity, and air friction on spindle power. Friction curves are presented from experimental data and compared with theoretical curves. General recommendations for improvement in bearing operation are given. *(Abstracter: H. N. Kaufman)* *(Cont'd on p. 231)*



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The Ford Rotunda, at the gateway to the mighty Rouge plant, houses spectacular animated displays, sculptures, murals and dioramas which illustrate the story of progress in the automobile industry. Tuesday's tour by the Ladies attending the Annual Meeting will include this Detroit landmark.

Welcome to Detroit

12th ASLE Annual Meeting & Exhibit

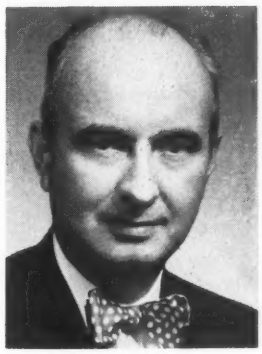
E. R. Booser, ASLE President

Members, guests, ladies and gentlemen: welcome to our 12th Annual Meeting and Exhibit. The 1957 meeting represents the fruit of planning which began more than 14 months ago. Results of this program may not be obvious for several months, perhaps years; and yet, each member, guest, and casual observer attending the meeting will look back upon the 1957 annual meeting as one which contained a significant number of new ideas, procedures, techniques, and practical information.

Departing from our traditional speaker, the banquet for this year's meeting has been patterned to fulfil two important areas which represent the "extracurricular" life of the engineer, chemist, and technician dealing with lubrication. Awards of recognition will be featured at the banquet as in past years, but to provide the needed diversion and relaxation, dancing and entertainment will follow this year's presentation of awards.

Each technical session registrant will depart from the meeting and exhibits with the latest information available for making his job more rewarding and his efforts more apparent to his employer. The preprints he carries with him are one of the newest services provided by the Society to fill the time gap between the presentation of a paper and its publication in the journal.

Carry with you the enthusiasm which the meeting and exhibits create, for with this enthusiasm you will foster even greater professional growth and individual recognition. Carry this enthusiasm back to your Section, technical and industry committee, for here it will spread to others not present at the meeting but actively pursuing the course of future meetings; paths which will see the Society and its members adding further to the productive standards of living through service to Industry and the public.



C. R. Lewis
Program Chairman

On behalf of your National Program Committee, we welcome you to the 12th Annual Meeting & Exhibit of the American Society of Lubrication Engineers.

We believe that this year's program covers all of the outstanding developments in the lubrication field. Authors from France and England indicate the far reaching scope of our Society and its influence on the lubrication field. Regardless of your position or interest in lubrication, we have tried to provide through the various sessions answers to your problems and technical information covering your interests.

We of the National Program Committee wish to express our many thanks to the various technical committees, organizing chairmen, and paper authors who assisted in the planning and organization of the Technical Sessions.

Mrs. James A. Brady
Chairman, Ladies Program

The Detroit members of ASLE and their wives are looking forward to entertaining the wives and guests attending the Annual Meeting at Detroit. The program has been carefully planned and will prove to be very interesting. It should be a very pleasant visit for those taking part in any of the activities.

Registration booth for the ladies in attendance will be open early Sunday afternoon. This will be a good time to renew old acquaintances and to become acquainted with the newcomers into our group.

Registration for the wives will be held again on Monday morning. The first activity for the ladies will be a luncheon to be held at the New Veterans' Memorial Building. Luncheon will be followed by a tour of Detroit's new Riverfront Civic Area, and will include the recently dedicated Henry and Edsel Ford Auditorium.

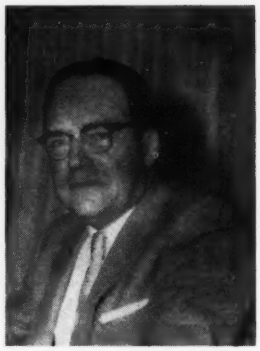
Tuesday's activities will begin with a partial tour of Detroit's new expressway system and a tour of Henry Ford's Fairlane Estate which was recently given to the University of Michigan to aid them in expanding their School of Engineering. The Ford Rotunda will be the next stop of interest. Originally this gear-shaped structure was erected at the Ford Exhibit during the 1934 Chicago World's Fair. In 1935, to provide a suitable hospitality center for the thousands who came to visit the vast Rouge Plant, the Rotunda was reconstructed on its present site. This building has attracted thousands of people from all over the world. Following this exhibit and display there will be a visit to the Ford Rouge Plant known throughout the world as the world's largest industrial city. To conclude this phase of the program we will visit the final assembly line.

Luncheon on Tuesday will be held at the Dearborn Inn. This will be followed by a visit to the world famous Greenfield Village.

Wednesday morning, transportation has been arranged for the ladies to visit J. L. Hudson's *Northland*, one of America's greatest shopping centers. No formal arrangements have been made for lunch on Wednesday.

Come early and plan to stay for the full convention program. We in Detroit anxiously await your arrival.

Welcome to the 12th Annual Meeting of ASLE from the members, committees, and officers of your host the Detroit Section. The local Section members will be recognized by the prominent green badge bearing the words, "Ask Me." The greeting means exactly what it says; our Section is pledged to assist the members and guests attending the meeting with any problems they may have in locating local points of interest. We wish to make your visit to Detroit a memorable experience of the hospitality and cooperation shown by members of the Society to out-of-town members and guests.



James A. Brady
Chairman, Detroit Section

Detroit, in addition to being the automobile center of the world, is one of the world's most concentrated industrial areas and employs several hundred thousand men and women to produce the machines and equipment which are a part of our daily lives' requirements. Local committees have checked every detail and program activity to provide the finest entertainment available. Warney Ruhl and his orchestra will provide dance music for those attending the banquet, and Jack Herbert will supply the comedy notes to keep the evening completely enjoyable.

This second national meeting held in Detroit will reflect the experience from our past meeting. We here in Detroit know you will enjoy the hospitality and cordial welcome which greets you.

George Spehn
Toastmaster

Jack Hubert
Comedian

Patti Brown
Vocalist

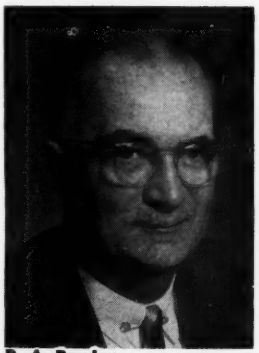
Warney Ruhl
and his Orchestra

Annual Meeting Authors & Abstracts

J. B. Accinelli
Shell Development Co.

A. J. G. Allan
E. I. duPont deNemours & Co.

E. C. Ballard
E. I. duPont deNemours & Co.



R. A. Baudry
Westinghouse Engineering Co.

The following Abstracts (of papers to be presented at the ASLE 12th Annual Meeting, April 15-16-17, 1957, Sheraton-Cadillac Hotel, Detroit) are published herewith for general information and to stimulate discussion at the meeting; they do not necessarily represent the final opinions of the authors and are subject to revision when the complete papers are published.

Apparent Adsorption Isotherms of Oleic Acid from Hydrocarbon Solution as Obtained from Coefficient of Friction Measurements, by A. Miller & A. A. Anderson. Boundary friction as a function of temperature of steel sliding on lead-base babbitt lubricated with various hydrocarbon solutions of surfactants was investigated with the friction pendulum. Certain regular relationships between the coefficient of friction vs. concentration isotherms were observed which resembled simple monolayers adsorption. A Langmuir treatment was applied expressing the surface coverage in terms of coefficients of friction of the carrier fluid, surfactant, and the given blend. A number of dilute solutions of oleic acid in hydrocarbon were studied at 60, 80, 100, 140, and 160°C., and the experimental friction-concentration data were found to fit monolayer-type isotherms in a satisfactory manner. Implications and limitations of the treatment are discussed, and application to potential problems given. (Preprint No. 57AM-4A-2)

Choose Your Press Drawing Lubricants with Care, by L. Salz. Press forming lubricants are frequently known to their users only by trade designations. The cloak of mystery surrounding this subject has resulted in the trial and error procedure being employed for the adoption of a product more often than can be justified in the light of technical information available. Actually, there are five principal classes of materials found in stamping and drawing lubricants. These are: oiliness agents, EP agents, emulsifiers, diluents, and inhibitors. From these categories, which are discussed in detail, the manufacturer selects appropriate components and blends them into a product that will do the required job. The individual component raw materials are carefully selected so that the finished product will provide the user with highest service efficiency with respect to die life and minimum rejects, ease of application and removal, non-corrosiveness, appeal to operators, and over-all economy. A recommendation chart is included which correlates the composition of stamping and drawing lubricants with expected performance on carbon steels, stainless and alloy steels, aluminum, copper, brass and bronze. (Preprint No. 57AM-2A-1)

Considerations in Filter Selection, by H. A. Wilson. The intent of this paper is to deal with several aspects of filter technology that are taken into account as design, test, and quality control features having a distinct bearing on field performance. The necessity of gathering factual operational data is stressed. Further, this data is weighed as to its significance, and interpreted in terms of filter requirements with emphasis on performance. The characteristics and physical considerations of certain filter media are compared. Laboratory techniques that assure predetermined filter media qualifications are explained. The entire discussion is aimed toward presenting in brief form some phases of filter technology that, it is hoped, the Lubrication Engineer will find to be helpful. (Preprint No. 57AM-6A-2)

Conversion Coatings Aid the Lubrication of Titanium, by E. L. White & P. D. Miller. Titanium and its alloys have a severe tendency to seize and gall when in moving contact with themselves or other metals. Lubrication of the bare metal has been successful only to a limited extent. Galling can be greatly reduced by using chemical conversion coatings with lubricants. Both anodic coatings and simple dip coatings hold lubricants effectively and eliminate or reduce galling in wear applications. The results of wear testing, wire drawing, and cold forming of sheet using conversion coatings are discussed. A satisfactory coating can be formed on titanium by anodizing in a 5 per cent solution of NaOH. A fluoride-phosphate conversion coating can be formed by simple immersions in a solution containing HF, KF, and Na_3PO_4. (Preprint No. 57AM-2A-2)

E. W. Baumgardner
Trabon Engineering Corp.

J. A. Bell
Shell Oil Co.

D. J. Boes
Westinghouse Research Labs.

W. L. Bulkley
Standard Oil Co. (Ind.)

S. R. Calish, Jr.
California Research Corp.

J. E. Cardillo
Ford Motor Co.

J. G. Carroll
California Research Corp.

J. F. Cerness
Clevite Research Center

Development of New Automotive Gear Lubricants, by T. P. Sands. This paper relates the past two years' activity in the upgrading of automotive gear lubricants. The necessity of determining the level of performance required by the axle builders led to the development of a reference gear oil system to be used as an engineering tool by the axle builders who then determined by tests of their own design their requirement in terms of the Reference System. Tests were developed in the laboratory, using full scale axles, of a severity level required to fail Reference Oils below the Performance Number desired by the automotive industry. (Preprint No. 57AM-5A-4)

Dislocation Theory Approach to Boundary Lubrication, Thin-Film Bearings & Wear-In, A, by J. H. Dismant. Friction is considered as a function of plastic and elastic deformation; the greater the elastic properties, the lower the friction. Boundary lubricants are considered to interfere with the generation of dislocations on surface metal thus increasing the elastic properties of this surface metal. It is demonstrated that at least one boundary lubricant, oleic acid, does tend to increase the elastic properties; i. e., the yield point strength of small coil springs made of 4 mil and 6 mil copper wire, but not on the larger 10 mil copper wire. The smaller wire sizes are considered near the upper limit of size for such an effect, but the yield point strength is apparently still increased by some 45%. This apparent effect of wire size is used as an explanation of the necessity for a wear-in period on lubricated wearing surfaces. Thin metallic films are considered to provide the same interferences with dislocations and, thus, low friction. (Preprint No. 57AM-4A-5)

Dynamic Oxidation Tester to Evaluate Grease or Ball-Bearing Performance at High Temperatures, A, by H. E. Mahncke & D. J. Boes. An instrument has been developed to evaluate the lubricating ability of greases in ball bearings, or the performance of the bearing itself, under actual operating conditions. By operating the bearing in an oxygen atmosphere held at a constant pressure, the total time required to test the grease has been shortened considerably. Furthermore, by measuring the amount of oxygen consumed during the test, the rate of grease oxidation is accurately measured. This data also aids materially in pinpointing more reproducibly the time of grease failure. Tests are made in a sealed chamber containing a single ball bearing packed with a measured quantity of grease. Testing temperatures from 70 to 300°C. are possible and, with slight modifications, a wide variety of bearing sizes can be used. The paper describes the test unit in detail. A summary of the results of tests made with the unit to date, including typical oxygen consumption curves and data showing the effect of variations in test bearings on grease life and test reproducibility, is also presented. (Preprint No. 57AM-4C-4)

Effect of Bearing Deformation in Slider-Bearing Lubrication, The, by F. Osterle & E. Saibel. The slider-bearing with the bearing elastic is analyzed for its load-carrying characteristics. The deflection of the bearing under load acts to reduce the load capacity by an amount which can be significant as is illustrated by a numerical example. (Preprint No. 57AM-2B-2)

Evaluation of Cutting Fluid Performance, by H. W. Husa & W. L. Bulkley. A test method is described for the comparative evaluation of cutting fluids under typical commercial rather than accelerated conditions. Measurements of tool wear rate, work surface finish, and cutting temperatures are used in the evaluation. Insufficiency of a single criterion of quality is illustrated, and use of composite measurements is stressed. Statistical interpretation of data is discussed. Transfer of radioactive material from a cutting tool to the chips produced in facing steel tubing in a lathe is used as a measure of tool wear rate. Use of low-activity tools with sensitive counting equipment simplifies personnel protection against radiation hazards. Techniques for obtaining surface finish measurements on surfaces representing average running rather than stopping conditions are described. Procedures for obtaining cutting temperatures while providing adequate chip breakage for wear measurements are outlined. Comparative results for compounded and mineral oils in the machining of AISI Type 1015, 1045, 4130 and 304 steels are reported. (Preprint No. 57AM-2A-3)

Filtration of Railroad Diesel Engine Oils, by W. K. Simpson. This subject is one of the most important items which controls the successful operation of our diesel engines in railroad service. Unfortunately, on a few railroads lube oil

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Humble Oil & Refining Co.

H. Gisser
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California Research Corp.

D. E. Grube
Owens-Illinois Glass Co.

filter performance is a neglected item. Although we have firm recommendations on oil filter handling, we have not been successful in selling the importance of good filter performance to all railroads. Two of the usual pitfalls are the use of poor quality filter elements or overextending the life of the filter. The use of poorer quality fuels and higher horsepower diesel engines has made the performance of the oil filters even more important. The construction of the locomotive oil system dictates the use of a bypass-type of filter housing. The inspection of the used oil filter elements themselves when they are removed is valuable in estimating the general performance level of the filters. Indications of sludging, bypassing, and collapsing of the elements may be easily detected as compared to the normal filter condition. A continuous analysis of used oil properties may be used to evaluate both cooler and filter performance. A review of the engine conditions, which may be directly associated with poor filter performance, emphasizes that the basic assumption that a railroad may save money by minimizing filter expenditures is completely in error. A conservative approach to lubricating oil filters and their performance level is the most satisfactory condition as far as diesel engine performance is concerned. (Preprint No. 57AM-6A-3)

Friction & Oil-Feed Characteristics of Journal Box Packing, by W. M. Keller & G. L. Pigman. An experimental investigation was conducted to determine the friction and oil feed characteristics of the cotton waste pack used for railroad journal bearing lubrication. The investigation also was extended to include wool and nylon fiber materials in place of cotton. An apparatus was constructed for this study in which the pressure force between the waste pack and journal could be controlled and measured, and the journal friction torque determined. A scraping technique was devised to measure the oil film thickness on the journal, as an indication of waste pack oil feed rate. It was found that the friction between the oil-saturated waste pack and journal arises from viscous shear of the oil. The coefficient of friction normally has values in a range from about 0.4 to 1.3. The total pressure force varies in value from about 2- to 150-lb., depending upon the waste pack condition. The friction heat generation from the waste pack normally is as great or greater than that associated with the railroad journal bearing. The oil film established on the journal by feed from the waste pack normally has a thickness from about 0.0001- to 0.0005-in. The oil film thickness decreases with increased oil viscosity, journal speed, and pressure force on the journal. The friction and oil feed properties of the waste pack are not affected in significant degree by change in waste pack fiber material. Principal gain in operating characteristics may be obtained by maintaining a minimum total pressure force between the waste pack and journal, and by reduction of contact area on the journal. (Preprint No. 57AM-5B-1)

Frictional Properties of High-Temperature Seal Materials, by J. F. Cerness, D. H. Strong & K. Pilarczyk. A group of selected materials have been tested at a surface speed of approximately 150 feet per second and a unit load of 18 pounds per square inch in the absence of liquid lubrication. The tests were performed at elevated temperatures in air or argon with moisture being added in some instances. The materials tested include Graphitar-67 (U. S. Graphite Co.), Superior R-24 (Superior Carbon Co.), electrodeposited chromium, S.A.E. 52100 steel, and ductile cast iron. The ductile irons in general result in high wear rates, high surface temperatures and high coefficients of friction when run against themselves. The graphite particles present as a constituent of ductile iron apparently do not serve as an effective solid lubricant at elevated temperatures. The carbon-graphite materials perform with varying wear rates against the ductile irons, S.A.E. 52100 steel, and chrome plate. There appears to be a definite temperature limitation for these materials in air as shown by very high instantaneous surface temperatures and torque when the temperature becomes excessive. The influence of moisture and atmosphere on running properties is illustrated by a series of tests with Graphitar 67 versus chrome plate. Moisture reduces the wear rate and coefficient of friction of this combination in argon. The wear rate of Graphitar-67 in air is between the wear rate in moist and dry argon. (Preprint No. 57AM-1A-2)

Grease Lubrication of Ultra-High Speed Rolling Contact Bearings, by J. B. Accinelli. The failure mechanisms of grease-lubricated ball bearings operating in the DN range from 1.0×10^6 to 2.0×10^6 was studied. A new rig capable of controlled operation of 20 and 25 mm ball bearings at speeds

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H. W. Husa
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J. W. Johnson
Atlantic Refining Co.

R. L. Johnson
NACA, Lewis Flight Prop. Lab.

up to 100,000 rpm is described. Ball separator design seems to be a very important factor, and a lightweight single-piece machined outer-ring-controlled ball separator appeared to give the best results. In general, mechanical factors such as vibration, bearing design, bearing fit and tolerances, dynamic balance, load alignment, etc., have more influence on the performance of the bearings studied than gross grease variables. Under ideal conditions, it is indicated that adequate lubrication with grease is possible for periods over 100 hours. However, under the test conditions generally in existence in the ultra-high speed rigs, grease lubrication was only adequate for very short periods. Grease compositional factors leading to better performance are smooth texture and hard consistency. At the temperature investigated, diester-type oil was slightly superior to mineral oil and greatly superior to silicone-base oil. (Preprint No. 57AM-4C-1)

Increased Machine Productivity Demands Well-Designed Lubrication Practices, by R. H. Guy. Improvements in metal alloys have enabled machine builders to design more productive tools. Hydraulic and electrical improvements have allowed them to interlock machine components together for greater labor savings. It is necessary to efficiently design petroleum storage and dispensing facilities, and to train maintenance personnel to gain the maximum production return from this newer style equipment. The preventive maintenance and cost records program must be renovated to receive major benefits from the large capital investment required to automate production processes. The Lubrication Engineer becomes a coordinator of the efforts of lubricant device manufacturers, petroleum suppliers, and the machine tool builders. Before a specially designed machine tool can be built, the lubrication must be simplified, the application method determined, and the coolant system agreed upon. "Pre-quotation" conferences are utilized to discuss and present an interchange of ideas and desires. Accessory manufacturers are alerted to educate the tool builders on the limitations and proper installation of their equipment. Lubrication engineering must be extended to find the answers to the new problems developing. More knowledge is needed as to the minimums and optimum amounts of lubricant to be applied; better methods of prebreakdown warnings at a reasonable cost is desired; industry-wide lubrication standards would assist the machine tool builder; and more intensive education of the machine tool builders in the phases of Lubrication Engineering would be advantageous to machine buyers. Volume manufacturers realize that integration of machines is inevitable to remain competitively active in today's and future markets. Therefore it behooves the lubrication industry to not allow the "oily film" be the weak link in the chain of production. (Preprint No. 57AM-4B-2)

Lubrication in a Glass Container Manufacturing Plant, by D. E. Grube. "Lubrication in a Glass Container Manufacturing Plant" describes the process of making glass bottles, beginning with the receiving of raw materials and following through until the container is packed ready for shipment. General description of equipment is given with comments on lubrication. Air compressors used to supply compressed air for the operation of the bottle forming machines are described with comments on lubrication. Lubrication of tractors is also discussed. (Preprint No. 57AM-3A-2)

Lubrication Standards for Industrial Equipment, by S. O. Kimball. The increase in mechanization of industrial plants has been accompanied by increases in maintenance problems. The JIC Standards have helped improve this condition, but lubrication has not yet been covered. As each manufacturer of industrial equipment has his own ideas on lubrication, a plant soon acquires a wide variety of lubrication devices and methods which may result in insufficient or improper lubrication and little or no repairs to the lubricating equipment. In many cases the lubrication provisions are not suitable to continuous high production operation and centralized oiling responsibility; lubrication points are hidden or inaccessible, and lubrication instructions and diagrams are non-existent. The lubrication engineers of a number of General Motors Divisions felt there was sufficient need for lubrication standards to stimulate engineered lubrication. The GM "Lubrication Standards for Industrial Equipment," on which this paper is based, were developed by the GM Shop Lubrication Subcommittee on Lubrication Standards "for the purpose of providing specifications for the application of lubrication to industrial equipment so as to provide for safety of personnel, continuous production, long life of the equipment, good house-

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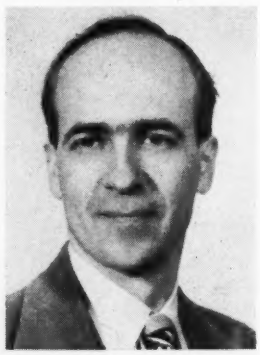
Assoc. of American Railroads



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AiResearch Manufacturing Co.

H. E. Mahncke
Rayonier, Inc.

keeping, and standardization of lubrication equipment and method," and are described in the paper. (Preprint No. 57AM-3A-1)

Mass Data Study of Separator Effect on the Starting Torque of R4D Bearings, by J. C. Lawrence, R. V. Milligan & P. E. Campbell. The results of the experiments reported herein show that within the sensitivity of the New Departure Bendix Commercial Torque Tester, 20 starts per bearing will give a good representative starting torque vs. frequency of start histogram for a group of approximately 15 or more bearings. Under the controlled conditions of the Rensselaer Polytechnic Institute instrument bearing laboratory, starting torque histograms are reproducible and creditable to within ± 1.5 torque cells, i.e. ± 0.0375 gm-cm. In an attempt to determine the effect of separator type on starting torque, it was found that all the values of mean starting torque of all bearing groups tested with "L," spring, and ribbon separators and no separators fell within the range of ± 1.5 gm-cm; hence, no conclusive evidence can be given for the individual effects of the various separators on starting torque with the present instrumentation. (Preprint No. 57AM-4C-3)

Measurements on Polymer-Modified Lubricating Oils at High Rates of Shear, by W. Philippoff. The experimental check described proved that viscosity measurements on polymer-modified oils with rotational and capillary viscometers can be successfully correlated. The rules for this are the same as those used for other non-Newtonian liquids (solutions of high polymers); namely, viscosity vs. the rate of shear at the wall, D. This is valid to at least 10^6 sec^{-1}. This correlation has been made with the highest precision ever obtained in any system investigated up to now. (Preprint No. 57AM-3C-2)

Mechanism of Tungsten Disulfide Lubrication in Vacuum, by M. T. Lavik, G. W. Vaughn & G. E. Gross. The lubrication behavior of WS_2 in high vacuum has been investigated and found to be similar to that of MoS_2. The steady-state value for the coefficient of friction at room temperature is found to be 0.065. When sliding is resumed, following a "stop-time," the coefficient of friction is initially high. However, it drops rapidly and approaches the equilibrium value within a few minutes. The adsorbed sulfur layer concept, hypothesized by Johnson for MoS_2 lubrication, is extended to explain the behaviour of WS_2. (Preprint No. 57AM-5C-3)

Mill & Laboratory Evaluation of Oils for Rolling Copper Alloys, by F. L. Reynolds. The general problem of lubricant evaluation in metal processing applications has been very difficult to approach because of the wide number and complexity of conditions. Differences in metal alloys and tooling, and the equipment in which the operations take place, provide innumerable and rapidly changing variables. In an attempt to meet three major conditions—load carrying, stain resistance during annealing, and demulsibility during reclaiming—a test operation was set up for mill testing of roll oils. Load-carrying tests were conducted on the basis of temperature measurement of strip before and after rolling, utilizing a contact thermocouple, and comparison of the figures obtained with the calculated temperature of deformation. Stain testing was done by examination of annealed material after pickling, and demulsibility was checked by sediment and water tests after reclamation of the oil. As indicated by the use of well-known and often-used oils during preliminary tests, the results compared favorably with known performance. To relieve the mill testing program, laboratory tests were devised and correlation attempted. Load testing was done on a tester equipped with a steel roll running against a brass block; stain tests were made using tight oil-soaked coils of brass strip in an electric furnace; demulsibility was checked through a modified ASTM steam emulsion test. Fair correlation, sufficient for preliminary testing and general prediction of mill results, has been obtained. (Preprint No. 57AM-6B-2)

Performance of an Inorganic Microgel Grease in Industrial Applications, by J. A. Bell. The development of an inorganic microgel grease is briefly reviewed, and laboratory evaluation test data presented to illustrate its general properties. Performance in a variety of industrial applications in comparison with other gases is discussed. These field evaluation studies show the microgel grease to perform satisfactorily over a broad temperature range under either dry or wet operating conditions. It is concluded the micro-

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G. E. Peterson
Westinghouse Engineering Co.

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Franklin Institute

gel grease is more "multi-purpose" than a typical lithium-base multi-purpose grease. (Preprint No. 57AM-2C-1)

Plastics as Solid Lubricants & Bearings, by A. J. G. Allan. Recent studies on the fundamental aspects of friction and wear of plastics are reviewed with particular reference to polytetrafluoroethylene. It is suggested that differences reported in the friction of polytetrafluoroethylene may be related to differences in the mechanism of shearing at the areas of intimate molecular contact. A review of wear data shows that the wear of polytetrafluoroethylene depends markedly on conditions of load and speed and the presence of fillers. It is possible that these differences are related to the differences in friction. In conclusion, some recent applications of polytetrafluoroethylene and nylon bearing surfaces are described in relation to the physical characteristics of the materials. (Preprint No. 57AM-5C-1)

Preparation of Highly Effective Rust Inhibitors by Fractionation of Mahogany Sulfonates, by K. R. Fisch, J. Messina & H. Gisser. Very effective rust inhibitors were prepared by the fractionation of commercial mahogany sulfonates. The fractionation was accomplished by continuous extraction of a solution of the sulfonate in 50 percent isopropyl alcohol with petroleum ether. Equivalent weight and rust preventive effectiveness of the fractions were determined. It was found that the rust preventive effectiveness of the fraction of highest equivalent weight was approximately three times that of the original material. The highest equivalent weight was 550, calculated as the sodium salt. Infrared measurements indicate that the fractions are all similar, and that the structure is that of an alkylated benzene sulfonate. The similarity of the infrared curves and the equivalent weights of the fractions indicate that the differences among the fractions are in the size and, possibly, in the configuration of the alkyl sidechain and the number of naphthenic rings. (Preprint No. 57AM-1B-2)

Review of Recent Russian Research on Chemisorbed Lubricant Films, by D. Godfrey. This paper lists Russian organizations where lubrication research is conducted, scientific Russian publications, and translation services in the U. S. The Russian research is varied, comprehensive, methodically conducted, and represents a great deal of time and effort. Their papers are well worth examining. Russian and Western procedures are similar, but the Russian research appears to be less advanced. The Russians are actively engaged in studies of the kinetics of lubricant additive action. Radioactive isotopes of S and P are used to measure amounts of film formed. Sulfur and phosphorus adsorption increased to a maximum amount with increase in concentration of additive, temperature, and time of immersion. These results, coupled with many four-ball machine wear tests, led the Russians to conclude that the effectiveness of such additives lies in a protective film mechanism. Surface-active molecules decrease metal plasticity during deformation. The application of this mechanism to the shearing process of cutting is an important contribution in the field of cutting oil additives. (Preprint No. 57AM-4A-4)

Service Experience with a New Multipurpose Industrial Grease, by S. R. Calish, Jr. The discovery of a new synthetic gelling agent has led to the development of a multipurpose industrial grease having widespread application. The novel thickener has made it possible to realize the advantages of a multipurpose lubricant without undue compromise of the important lubrication properties obtained with specialized greases. Because the new grease is compatible with all known grease types, no special precautions are required to introduce it into an existing lubrication system. The paper outlines the necessary performance characteristics for greases in many major industries, and emphasizes the limiting environmental conditions for each. Specific examples of product application in unusual or severe service are cited. (Preprint No. 57AM-2C-2)

Some Effects of Gamma Radiation on Commercial Lubricants, by J. G. Carroll & S. R. Calish, Jr. In order to survey their utility in atomic reactors, twenty-eight lubricants were exposed to gamma rays. Included were four base oils (pale oil, neutral oil, white oil, and bright stock), four industrial oils, two gear lubricants, an automatic transmission fluid, three industrial greases, and three multipurpose greases. Exposures ranged from 10^8 to 9×10^8 roentgens at about 80°F. Tests showed that the effects of radiation on compounding in lubricants are probably more limiting than the effects on the base oil. Certain commercial lubricants are useful for a gamma dosage of at least 10^8 roentgens. (Preprint No. 57AM-1B-1)

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E. Saibel
Carnegie Institute of Technology

Some Mechanical Considerations in the Design of Large Thrust Bearings, by R. A. Baudry & G. E. Peterson. The modern thrust bearing is a very important part of the water-wheel generator, for it must support the weight of the rotating parts of the turbine and generator and the hydraulic thrust load. With the continuous increase in size of hydroelectric generating units, machines now are built with thrust loads well above 1000 tons and requiring bearings ten feet in diameter or larger. Continuous trouble-free operation for periods of twenty years or more are desired for the bearings of large hydroelectric units. Except during the starting period, the pivoted-pad thrust bearing operates according to the well-known hydrodynamic theory of lubrication which permits the predetermination of its performance with reasonable accuracy. Alternating slipping between the thrust bearing runner and the supporting structure can result in excessive wear which destroy the accuracy of the bearing surfaces. Such wear can cause undesirable vibrations or damage to the bearing surface which prevents the formation of an adequate oil film. As a result of laboratory tests and experience in the field, it is now possible to make large thrust bearings with a supporting structure which will permit them to operate continuously for long periods of time with practically no wear or loss of adequacy. (Preprint No. 57AM-2B-3)

Teflon for Dry Lubricant Bearings, by S. B. Twiss, P. J. Willson & E. J. Sydor. Friction experiments with a number of reinforced Teflon (polytetra fluoroethylene) compositions and resin-bonded Tenon-filled plastic bearings are discussed. Fillers for Teflon consist of powders such as iron oxide, asbestos, coke flour, glass fibers, zirconia, copper, graphite, and molybdenum disulfide. Resin-bonded compositions consist essentially of a modified phenolic resin binder, fillers, and Teflon powder. With either type of composition, a reduction in speed from 625 to a few feet per minute appeared to have no effect on the coefficient of friction; however, in the low speed range most compositions showed a marked drop in friction. The effect of load on friction, in the range of 30 to 250 psi., appears to be minor. The effect of temperature in the range of 100-300°F. is quite variable with the resin-bonded compositions. Increasing temperature appears to give increased friction with some of the reinforced Teflon materials. Comparison of both types of Teflon compositions with other plastics and dry lubricant compositions shows the Teflon materials to have a more consistently low friction when run dry under the conditions of these experiments. The chief advantage of the resin-bonded compositions for bearing use is their higher compressive strength as compared with reinforced Teflon. (Preprint No. 57AM-5C-4)

Threading Test for Cutting Oil Evaluation, A, by H. A. Hartung, J. W. Johnson & A. C. Smith, Jr. A laboratory evaluation test for cutting oils based on the threading operation has been successfully used over a number of years for laboratory development work and for evaluation of field samples. The test involves generating a thread under regulated conditions, measuring the torque required. The equipment used is described in some detail, as are the factors which must be controlled carefully to make the test work. The geometry of threading processes is developed. Experimental laboratory data on a number of additives are included. Tool temperatures have been measured and found

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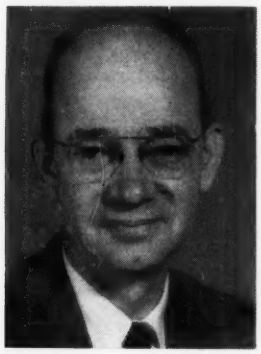

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to agree well with other published data. Finally, the correlation between laboratory and field results is shown to be good for a number of different machining operations. (Preprint No. 57AM-2A-4)

Vacuum Dehydration of Oils, by G. J. Topol. Water is usually more detrimental to the performance and life of lubricating oils than solid contaminants. Water in oil can impair its lubricating properties and cause costly corrosion. Finely dispersed in the oil, water can cause severe damage to the oil by increasing the rate of oxidation and sludge formation. The increasingly severe requirements of modern equipment on lubrication have necessitated the development of new lubricating oils. These oils are, in general, more susceptible to water contamination than straight mineral oils. Conventional methods of water removal are inadequate for most additive oils. Of the possible methods of water removal, vacuum dehydration of oils appears to be the most universally effective. A study of physical properties of dispersed water reveals some interesting facts leading to a new approach to vacuum dehydration. The new process uses a special porous medium to accelerate vaporization. The processing rate and temperature are automatically adjusted to the degree of contamination. The principles applied in this process provide the additional benefit of solid filtration and degasification. Field experience shows that vacuum conditioning of oils, previously considered complicated and costly, becomes simple and economical by the new method. (Preprint No. 57AM-1C-2)

Wear & Frictional Chracteristics of Some Wrought & Cast Nickel-Base Alloys, by R. A. Kozlik. This paper describes the results of a program that was undertaken to determine the relative resistance to wear and galling of a variety of wrought and cast nickel-base alloys. Testing was done using a breakdown technique on an Amsler wear tester that was operated so as to produce sliding, at the contact surfaces, at a rate of about 512 feet per minute. The wear rate, galling behavior, and frictional characteristics were determined both without a lubricant and with a light turbine oil as the lubricant. The alloys tested included those in the wrought nickel, Monel and Inconel families, as well as their cast counterparts. The effectiveness of several coatings in improving the resistance of some of the alloys to wear and galling is briefly discussed. (Preprint No. 57AM-6B-1)

Wear of Carbon-Type Seal Materials with Varied Graphite Content, by M. A. Swikert & R. L. Johnson. Most carbon-type seal materials contain graphitic carbon as the minor constituent. Materials having graphitic carbon as the major constituent were studied as possible seal materials at 10,000 feet per minute sliding velocities; the usual temperature of the mating surfaces was 500°F. Carbon materials made graphitic by electrographitization were too soft; they gave high wear and high friction. Bodies molded with high graphite-content-materials and made hard by improved molding methods and impregnation gave good friction and wear properties. The effect of orientation of graphite with respect to wear plane had a small effect on wear with a conventional seal material. Using a hardenable stainless steel, the effect of varied hardness of mating surface on wear of typical carbon was slight. Within a limited range, roughness of mating surface is not important to wear of carbons. (Preprint No. 57AM-1A-1)

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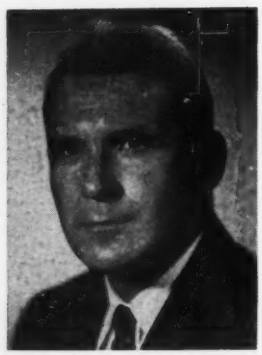

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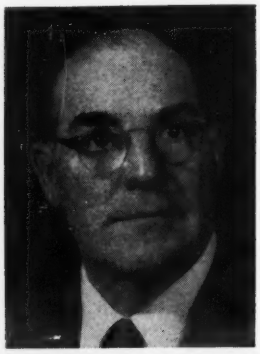

H. A. Wilson
Commercial Filters Corp.

(Lube Abstracts, from p. 219)

"Modern Lubricants Need Great Care," by E. W. Fair, *Textile World, Vol. 106,* No. 10, October 1956, pp. 107-111. A review is presented of the hazards resulting from improper purchasing, storage, handling, and application of the delicately-balanced, compounded oils used in textile lubrication. *(Abstracter: E. S. Reynolds)*

"Storing & Handling Lubricants," by R. K. Gould, *Diesel Power, Vol. 34,* No. 2, February 1956, pp. 40-41. A review is presented of basic rules to be followed in proper handling, storing, dispensing, and application of modern precision-compounded lubricants. It is pointed out that damaged equipment, excessive maintenance costs, accidents, and decreased production can result from ineffective handling and storing, through deterioration of the lubricant. Examples of types of deterioration, with conditions causing them, are given. *(Abstracter: E. S. Reynolds)*

(Foreign Abstracts, from p. 214)

al, "Metallovedenie I Obrabotka Metallov," Vol. 2, No. 4, 1956, pp. 50-56; 6 figs., 4 tables, 1,900 words. Setup for testing model rotor and guide blades for erosive wear by fuel ash particles such as would be encountered in turbines running on solid fuel (Figs. 1-3). Difference in erosion resistance between rotor blades and guide blades. Erosion resistance of various austenitic steels before aluminizing (and chromizing). Micrographs of specimens aluminumized and aluminized plus chromized, and also homogenized (Fig. 4). Effect of aluminizing alone and coupled with chromizing under stated sets of conditions, upon erosional wear resistance and on mechanical properties. Conclusions drawn for practical application. (Order No. 3805, price $4.75)

Sulfidizing (of Steel & Cast Iron) in Fused Salts, by E. M. Morozova & F. R. Florensova, "Stanki I Instrument," Vol. 27, No. 5, 1956, pp. 27-30; 8 figs., 5 tables, 2,100 words. Sulfidizing of alloy structural steels and cast irons in baths containing potassium ferrocyanide, sodium hydroxide, and sodium thiosulfate. Composition of bath giving the best depth of sulfidizing and the highest concentrations of sulfur and nitrogen in surface zone; effect of duration of sulfidizing treatment. Microstructure of steel and cast iron specimens (in part with high initial sulfur contents) treated. Mechanism of saturation with sulfur and nitrogen; simultaneous formation of iron oxides in case, and effect of presence of potassium ferrocyanide in bath upon these iron oxides. Influence of sulfur impregnation on hardness, wear resistance, and coefficient of friction. Advantages of sulfidizing of components operating at high speed under lubricant-starved conditions. (Order No. 3839, price $4.85)

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APRIL 16-18, National Petroleum Association (Semi-Annual, Meeting) Hotel Cleveland, Cleveland, Ohio.

18, National Industrial Conference Board (Meeting of Board), Waldorf-Astoria Hotel, N. Y. C.

18-19, American Society for Engineering Education (Southwest Section Meeting), Texas A & M College, College Station, Tex.

22-24, Canadian Institute of Mining & Metallurgy (Annual General Meeting), Chateau Laurier Hotel, Ottawa, Canada.

24, Association of Consulting Chemists & Chemical Engineers (Banquet & Symposium), Belmont Plaza Hotel, N. Y. C.

24-25, National Industrial Research Conference, Conrad Hilton Hotel, Chicago, Ill.

24-26, Institute of Radio Engineers (Regional Conference & Trade Show), U. S. Grant Hotel, San Diego, Calif.

24-27, Florida Engineering Society (Annual Convention), Angebilt & San Juan Hotels, Orlando, Fla.

25, Vermont Society of Engineers (Annual Meeting), Woodstock Inn, Woodstock, Vt.

25-26, American Society of Mechanical Engineers (Conference with Society for Advanced Management), Statler Hotel, N. Y. C.

25-26, American Society of Mechanical Engineers (Railroad Conference), Sheraton Hotel, Chicago, Ill.

25-27, American Physical Society (Regional Meeting), Washington, D. C.

26-27, American Society for Engineering Education (Allegheny Section Meeting), Penn. State Univ., University Park, Pa.

27, Conference on Tool Engineering, Purdue Univ., W. Lafayette, Ind.

29 thru May 1, American Oil Chemists' Society (Annual Meeting), Roosevelt Hotel, New Orleans, La.

29 thru May 1, Association of Iron & Steel Engineers (Spring Conference), Hilton Plaza Hotel, Cincinnati, Ohio.

29 thru May 2, Society of Aeronautical Weight Engineers (16th Annual National Conference), Broadview Hotel, Wichita, Kan.

29 thru May 3, American Material Handling Society (7th national Materials Handling Exposition), Convention Hall, Philadelphia, Pa.

MAY 1-3, Society for Experimental Stress Analysis (Spring Meeting & Exhibit), Statler Hotel, Boston, Mass.

3, 4th Annual Conference for Engineers & Architects, Ohio State Univ., Columbus, Ohio.

3-4, New Jersey Society of Professional Engineers (Annual Convention & Exhibition), Hotel Ambassador, Atlantic City, N. J.

5-9, American Ceramic Society (59th Annual Meeting), Statler-Hilton Hotel, Dallas, Tex.

5-11, 2nd Cuban Petroleum Congress (Industry Exhibit, and Technical & Scientific Sessions), Havana, Cuba.

6-8, American Petroleum Institute (Lubrication Committee), Grand Hotel, Point Clear, Ala.

7-9, American Institute of Electrical Engineers (Aircraft Electrical Equipment Conference), Dayton, Ohio.

9-10, Conference on Engineering Graphics, Purdue Univ., W. Lafayette, Ind.

9-10, Conference on Managerial Controls, Illinois Inst. of Tech. Campus, Chicago, Ill.

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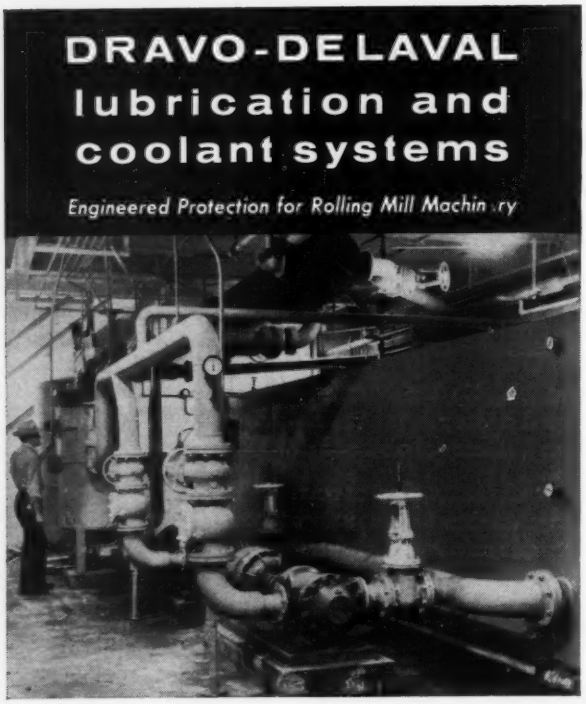

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Patent Abstracts

(Compiled by Ann Burchick, Aluminum Co. of America.)

Soluble Cutting Oil, Patent No. 2,744,070 (E. R. Baker & E. W. Nelson, assignor to Continental Oil Co.) An improved soluble cutting oil adapted for emulsification with water in the proportion of one volume of soluble oil to from 2 to 100 volumes of water to form a cutting and cooling composition, said soluble oil consisting essentially of a major proportion of a hydrocarbon oil of cutting oil viscosity and minor amounts of an emulsifying agent, a chlorine-containing antiseize agent, and a high sulfur content olefin-derived polysulfide extreme pressure agent prepared by first reacting a non-conjugated olefinic hydrocarbon having from at least 6 to about 30 carbon atoms with about a stoichiometric equivalent of sulfur chloride at a temperature of from about 0 to about 50°C. for a time sufficient to form a di(chloro alkyl)sulfide intermediate but not to exceed about 3 hours in the presence of a water-soluble aliphatic alcohol and then at once condensing said intermediate with a water-soluble inorganic higher polysulfide at about 50 to 100°C. in a mutual solvent for a time not to exceed about four hours, the emulsifying agent being present in amounts between about 10 and 40 per cent sufficient to form a stable emulsion, the antiseize agent being present in amounts sufficient to impart about 2 per cent added chlorine to the oil, and the olefin-derived polysulfide being present in amounts sufficient to impart from 1.25 to 2 per cent added sulfur to the soluble oil.

Lubricating Oil Additives, Patent No. 2,744,071 (W. C. Hollyday, Jr., assignor to Esso Research & Engineering Co.) A lubricating oil composition having outstanding low temperature properties which comprises a major portion of a mineral lubricating oil and a pour point depressing amount of a polyamide, of sufficient molecular weight to be oil soluble, of substantially equimolecular amounts of an amine constituent, selected from the group consisting of diamines.

Metal & Sulfur-Containing Compounds and Lubricants Containing Them, Patent No. 2,744,083 (L. E. Moody & E. B. Cyphers, assignors to Esso Research & Engineering Co.) An improved composition of matter, a derivative, containing both alkaline earth metal and sulfur atoms, of an alkyl phenol having 5 to 20 carbon atoms in the alkyl group wherein the sulfur has been introduced into said derivative by at least one sulfurizing agent selected from the group consisting of sulfur chlorides, elemental sulfur and sulfides of phosphorus, said derivative having been treated with a stabilization agent selected from the group consisting of mercaptobenzothiazole, diphenylguanidine and mixtures thereof in an amount in the range of about 0.1% to 20% by weight based on said derivative, said treatment being carried out at a temperature in the range of 275 to 600°F. for a time sufficient to produce a substantially stable, non-corrosive product.

Lubricating Compositions, Patent No. 2,744,870 (C. Stillebroer & J. L. van der Minne, assignors to Shell Development Co.) A lubricating composition for lubrication of internal combustion engines operating with high sulfur hydrocarbon fuels, said lubricating composition consisting essentially of a water-in-oil emulsion consisting essentially of from 5% to 40% by weight of water and from 60% to 95% of a mineral lubricating oil, said water phase of the emulsion containing in solution at least 0.25 gram mols per liter of a water soluble salt of a divalent metal.

Lubricating Composition, Patent No. 2,744,871 (P. H. Williams & L. B. Scott, assignors to Shell Development Co.) A lubricating composition adapted for extreme pressure use comprising a major amount of a water miscible mixture of monohydroxy oxyethylene oxy 1,2-propylene aliphatic monoethers in which the ethylene oxide and 1,2-propylene oxide are combined therein as oxyethylene and oxy 1,2-propylene groups in a ratio which is at least one third part of 1,2-propylene oxide for each part of ethylene oxide by weight, said mixture having an average molecular weight of at least 300 attributable to said groups, the aliphatic monethers of said mixture containing in a single molecule both the oxyethylene and oxy 1,2-propylene groups, and a minor amount between about 0.1% and about 5% by weight, sufficient to improve the extreme pressure properties thereof of boric acid.

Gear Lubricant Comprising a Wide Mineral Oil Blend and an Oxidized Paraffinic Residuum, Patent No. 2,744,874 (R. F. Nelson, assignor to The Texas Co.) A gear lubricant consisting essentially of about 30% to 35% by weight of an unoxidized heavy mixed base residual oil having a viscosity of about 700-750 seconds Saybolt Universal at 210°F., about 30% to 35% by weight of an unoxidized naphthenic distillate oil having a viscosity of about 50-75 seconds Saybolt Universal at 100°F. and about 30% to 35% by weight of a fluid cut back oxidized residuum having a Saybolt Furol viscosity of about 175-225 seconds at 210°F. and consisting of about 40% to 60% by weight of a naphthenic distillate

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oil having a viscosity of about 75-125 seconds Saybolt Universal at 100°F. and about 40% to 60% by weight of an oxidized residuum having a penetration of 77°F. of about 55-75, obtained by oxidizing a paraffinic cylinder stock residuum having a viscosity of about 100-150 seconds Saybolt Universal at 210°F.

Process for Preparing Lubricating Compositions, Patent No. 2,745,810 (A. J. Morway & L. C. Dawson, assignors to Esso Research & Eng. Co.) A process for the preparation of channeling type high temperature antifriction bearing lubricating grease compositions which comprises the steps of admixing with a mineral base lubricating oil from 20% to 50% by weight of a grease forming complex soap, heating to a temperature sufficient to completely dissolve said complex soap, rapidly cooling said heated mixture to a temperature below the transition temperature of the soap, then adding a quantity of a mineral lubricating oil having a viscosity index substantially higher than that of said base oil, said quantity being sufficient to result in a formulation containing from 6% to 18% by weight of soap and subjecting the mixture to the action of rates of shear in the order of 10,000 to 500,000 reciprocal seconds under streamlined conditions to obtain a grease composition having an ASTM penetration within the range of from 200 to 350 mm./10.

Alkylene Oxide Condensate of Discard Palm Oil, Patent No. 2,745,855 (E. N. Case, assignor, by mesne assignments, to Sinclair Oil & Gas Co.) The condensation product prepared by condensing discard palm oil with an alkylene oxide having two to three carbon atoms in which the weight ratio of alkylene oxide to discard palm oil is in the range of about 0.2 to 2.5.

Estersil-Thickened Lubricating Composition Modified with Hydrogen-Bonding Donor Compound, and Process of Making, Patent No. 2,746,922 (R. O. Braendle, assignor to E. I. duPont deNemours & Co.) A lubricating composition comprising a major proportion of a mixture of a water insoluble lubricating oil and a solid which is organophilic, being preferentially wetted by butanol in a butanol-water mixture, said solid comprising a supercolloidal substrate coated with—OR groups, the substrate having a surface of silica and having a specific surface area of from 1 to 900 square meters per gram, the coating of—OR groups being chemically bound to said silica, R being a hydrocarbon radical of from 2 to 18 carbon atoms wherein the carbon atom attached to oxygen is also attached to hydrogen, and a hydrogen bonding donor compound in which every electron donor atom is attached by at least one primary valence bond to an element other than silicon, the proportion of donor

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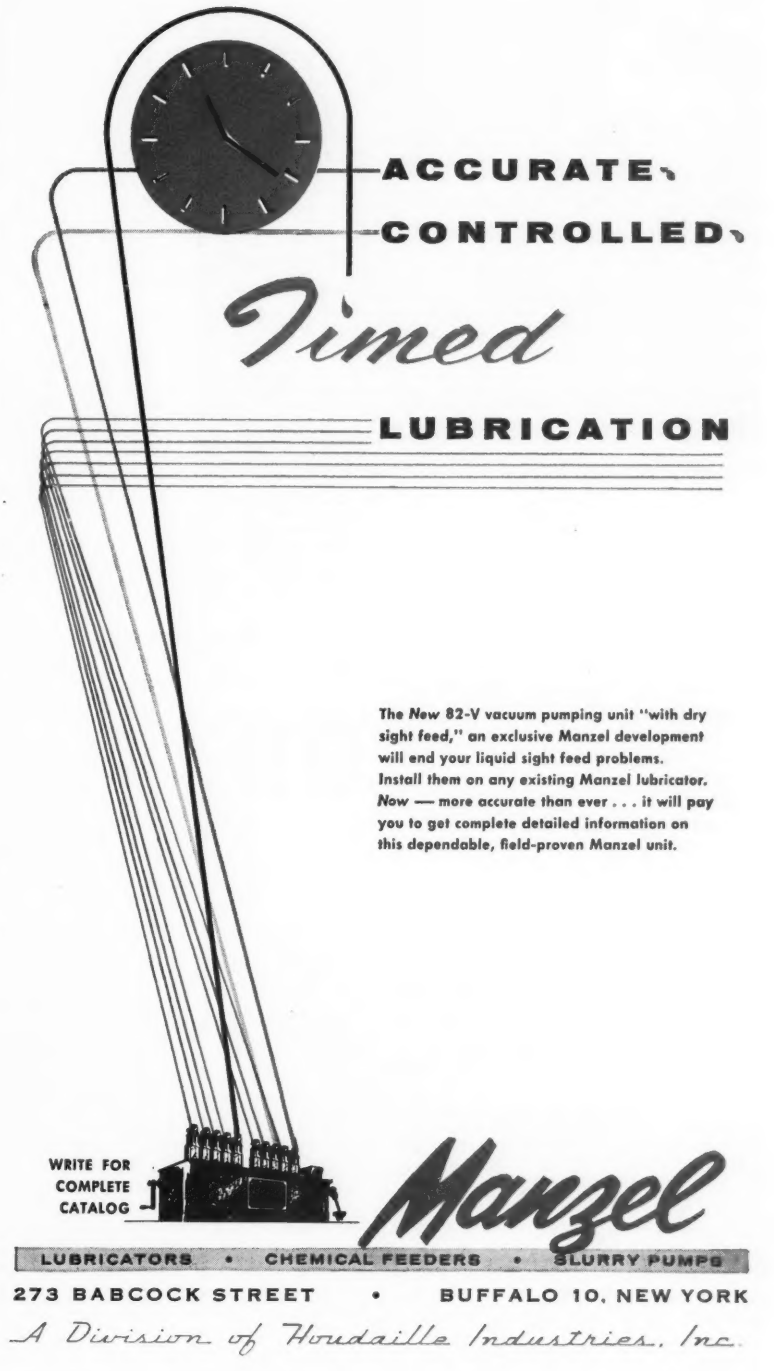
compound in the composition being about from 0.1% to 8.5% by weight.

Synthetic Oil Base Lubricating Grease Compositions, Patent No. 2,746,924 (D. L. Cottle, D. W. Young & A. J. Morway, assignors to Esso Research & Engineering Co.) A lubricating composition which comprises a formal of the formula: $(RO)_2CH_2$, wherein R is a highly branched chain aliphatic radical corresponding to that of an alcohol having from 8 to 20 carbon atoms made by the interaction of an olefin with carbon monoxide and hydrogen in the Oxo process containing combined therein a grease forming amount of a metal soap.

Lubricants and Additives Therefor, Patent No. 2,746,925 (J. D. Garber, W. C. Hollyday & B. M. Vanderbilt, assignors to Esso Research & Engineering Co.) In a process for the formation of copolymers having the desirable characteristic of lowering the pour point and increasing the viscosity index of mineral lubricating oils with which they are blended wherein from 75% to 25% of a mono-olefin containing from 8 to 20 carbon atoms in a straight chain is copolymerized with from 25% to 75% of an olefin of substantially lower molecular weight containing from 2 to 6 carbon atoms, in the presence of an inert solvent acting as a refrigerant in the process and a Friedel-Crafts catalyst at a temperature within the range from —105° C. to 0°C. to form a copolymer having a molecular weight within the range of from 3,000 to 6,000, the improvement which comprises mixing a solution of the Friedel-Crafts catalyst in inert solvent with the mono-olefin containing from 8 to 20 carbon atoms in a straight chain, and thereafter adding to the resultant mixture the lower molecular weight olefin containing 2 to 6 carbon atoms.

Water-Resistant Non-Soap Grease Containing Alkaline Agents, Patent No. 2,748,081 (W. H. Peterson & T. Skei, assignors to Shell Development Co.) A grease composition comprising a water-insoluble lubricating oil having dispersed therein an inorganic grease-forming gel of the group consisting of silicate gels and silica gels, said gels having their normal water content replaced by the lubricating oil and having adsorbed on the surfaces thereof between about 25 and about 100% by weight of the gel of a cationic hydrophobic surface-active agent, and an inorganic water-soluble alkali metal alkaline agent in an amount between about 0.1 and about 1% by weight of said grease, said alkaline agent when dissolved in water causing the pH thereof to be above 9.5.

Lubricating Compositions, Patent No. 2,748,082 (J. Zachar, assignor to Shell Development Co.) A non-aqueous lubricating composition comprising a major amount of a mineral lubricating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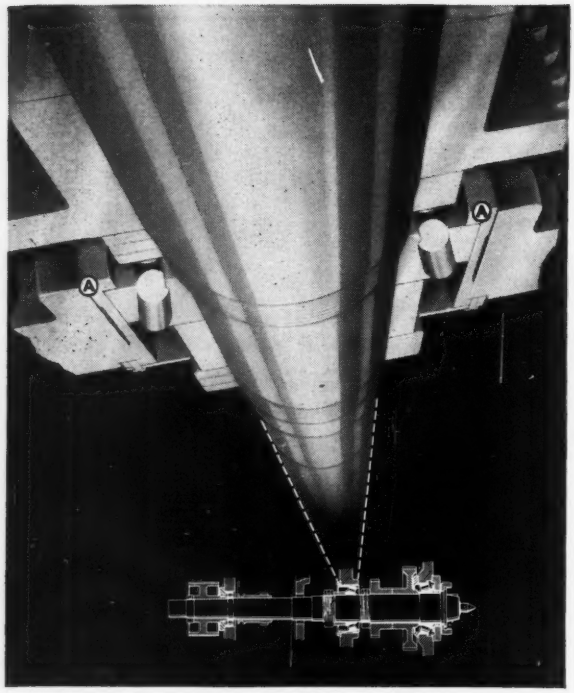

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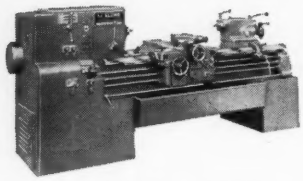

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oil and from about 0.5 to about 15% by weight of an oil-soluble petroleum sulfonamide derived from a petroleum fraction rich in aromatics.

Process for Inhibiting Foam, Patent No. 2,748,086 (L. T. Monson, assignor to Petrolite Corp.) A process for inhibiting foam characterized by subjecting a non-detersive foaming composition to the action of not more than 1 per cent of an acidic esterification product of a dicarboxy acid and a polyalkylene glycol in which the ratio of equivalents of dicarboxy acid to polyalkylene glycol is within the range of 1.1 to 2.0, in which the alkylene group has from 2 to 3 carbon atoms and in which the molecular weight of the product lies between 1,500 and 4,000.

Synthetic Lubricant Product of Polymerization of a Vinyl Ether with an Olefin, Patent No, 2,748,170 (G. J. Benoit, Jr. & A. D. Abbott, assignors to California Research Corp.) A lubricant composition comprising a reaction product obtained by reacting ethylene with vinyl butyl ether at a temperature of about 150°C. in the presence of a free radical initiating catalyst, said reactants being employed in the ratio of from about 0.1 to 0.5 mole of the ether per mole of ethylene, and distilling off from the resulting reaction mixture at least that portion thereof boiling below about 150°C. at 5 mm. Hg, leaving as residue the desired lubricant composition having an average molecular weight of from about 400 to 700.

Lubricating Compositions, Patent No. 2,749,310 (P. H. Williams & L. B. Scott, assignors to Shell Development Co.) A clear lubricating oil composition stable against phase separation comprising a major amount of a mineral lubricating oil and from about 0.1 to about 2% by weight each of boric acid, lecithin, and an oil-soluble 2-alkyl oxazoline compound containing in the 4-position a polar radical selected from the group consisting of a hydroxyl radical and a hydroxyalkyl radical.

Corrosion Inhibitors and Compositions Containing the Same, Patent No. 2,749,311 (A. R. Sabol, E. K. Fields & R. E. Karll, assignors to Standard Oil Co.) A new composition of matter, the oil-soluble reaction product of a mercaptan, formic acid and 2,5-dimercapto-1,3,4-thiadiazole, said reactants being reacted in the molar ratio of from about 1:1:1, respectively to about 3+x:1+x:x, where x is an integer from 1 to about 10, inclusive, respectively, at a temperature of from about 30 to about 250°F., said mercaptan having the general formula RSH in which R is an aliphatic hydrocarbon radical having from about 6 to about 30 carbon atoms.

Modified Polymeric Pour Point Depressants, Patent No. 2,749,312 (W. C. Hollyday, Jr., assignor to Esso Research & Engineering Co.) A lubricating composition which comprises a lubricating oil base stock containing combined therein a minor but pour point depressing proportion of the reaction product of an aliphatic monoamine having from 6 to 20 carbon atoms per molecule selected from the class consisting of primary monoamines, secondary monoamines and mixtures thereof.

Lubricating Grease Comprising a Synthetic Oil & a Complex Thickener, Patent No. 2,750,341 (A. J. Morway, D. W. Young & P. V. Smith, assignors to Esso Research & Engineering Co.) A lubricating grease composition comprising a major proportion of a substantially completely esterified complex dibasic acid-dihydric alcohol-monovalent substituent aliphatic ester oil base of lubricating grade and viscosity, said dibasic acid being selected from the group consisting of sebacic and adipic acid, said dihydric alcohol being triethylene glycol and said monovalent substituent being selected from the group consisting of ethyl hexanoic acid, ethyl hexanol and a mixture of C_{10} to C_{18} alcohols having an average of 13.5 carbon atoms, and 5 to 25% by weight, based on the total composition, of a performed complex soap thickener consisting essentially of alkali metal soap of fatty acid in the C_{10} to C_{22} range and alkali metal salt of a carboxylic acid having a molecular weight of below about 100, the molar ratio of said fatty acid soap to said carboxylic acid salt being in the range of about 0.5:1 to 2:1.

Lubricant Composition Containing Powdered Lithium Carbonate and Method of Its Application to Metal Bodies, Patent No. 2,751,312 (H. J. Ness, assignor to Metallurgical Processes Co.) The method of producing a high temperature lubricating film on the surface of a metal body which comprises heating the body to a temperature of from about 1150 to 2500°F. and spraying a material consisting essentially of powdered lithium carbonate onto said surface while the latter is in the open air to form a continuous fused coating thereof on said surface.

Water Resistant Lubricants Thickened with Inorganic Gelling Agents (Patent No. 2,751,349, W. A. Marshall & C. F. Steininger, assignors to The Pure Oil Co.) A gelatinous composition having lubricating qualities which comprises a major portion of an oleaginous lubricating liquid having incorporated therein a sufficient amount of an inorganic gelling agent to produce a gelatinous composition of greaselike consistency, the surfaces of said gelling agent being treated with a tin halide in an amount sufficient to impart water resistance characteristics to said composition.

Rust-Inhibited Silicate Base Oils, Patent No. 2,751,350 (R. L. Peeler, Jr. & E. G. Foehr, assignors to California Research Corp.) A machine gun lubricant comprising a major proportion of a silicate oil, from about 1 to about 3% by weight of a metal sulfonate, the metal being selected from the group consisting of lead and the metals of Group I and II of Mendeleeff's Periodic Table, and from about 1 to about 10% by weight of an alkyl polyalkylene glycol ether.

Complex Ester Base Lubricating Grease Compositions, Patent No. 2,751,351 (D. W. Young, A. J. Morway & D. L. Cottle, assignors to Esso Research & Engineering Co.) A lubricating grease composition which comprises a complex ester synthetic lubricating oil formed by esterifying one mol of a 1-3 glycol selected from the group consisting of butanediol-1,3, methyl butanediol-1,3 and pentanediol-1,3 with two mols of a C_4 to C_{10} dibasic acid and two mols of a C_8 to C_{12} branched chain alcohol, said oil being thickened to a grease consistency with from 2% by weight to 20% by weight, based on the total composition, of the lithium soap of hydrogenated fish oil acid.

Hydraulic Pressure Transmitting Fluid, Patent No. 2,751,356 (C. M. White & A. W. Sawyer, assignors to Genesee Research Corp.) A hydraulic pressure fluid consisting essentially of 5.0 to 30% of a synthetic lubricant from the group consisting of a polymerized ethylene glycol having a molecular weight of from 180 to 420, hexanetriol 1, 2, 6, tributoxyethyl phosphate, tributoxyethoxy ethyl phosphate and tricresyl phosphate, to 5.0 to 30% of a tall oil-potassium hydroxide soap and 40 to 89.9% of a solvent from the group consisting of aliphatic alcohols, glycols and glycol ethers, the amount of soap in no instance exceeding the amount of synthetic lubricant.

Hydrophobic Silica-Base Lubricants Containing 1,3-Diols as Anti-Gelation Agents, Patent No. 2,752,310 (J. W. Blattenberger, assignor to Sun Oil Co.) A grease composition comprising a major proportion of lubricating oil, colloidal hydrophobic silica gel dispersed therein in minor proportion sufficient to substantially thicken the composition, and a small amount sufficient to inhibit gelation upon heating of the composition of an aliphatic diol having 6-12 carbon atoms per molecule and having its hydroxyl groups attached to carbon atoms which are separated by one carbon atom.

Lubricant Containing a Metal Derivative of a Hydroxyarylalkyl Polyamine & a Metal Dithiocarbamate, Patent No. 2,752,311 (F. C. McCoy, J. M. Caffrey, Jr. & W. R. Hencke, assignors to The Texas Co.) A lubricant composition comprising a major proportion of a mineral lubricating oil having admixed therewith about 0.1-5.0 per cent by weight based on the weight of the composition of the methoxy magnesium derivative of N,N'bis(2-hydroxy-5-alkyl (C_{15-30})benzyl)-1,2-diamino ethane and about 0.1-5.0 per cent by weight based on the weight of the composition of

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Polyamide-Polyamate-Thickened Grease, Patent No. 2,752,312 (J. A. Dixon, assignor to California Research Corp.) A grease composition comprising a major proportion of a lubricating oil and, in an amount sufficient to thicken said lubricating oil to the consistency of a grease, a grease thickening agent selected from the group consisting of polyamic acids.

Lubricating Tetrafluoroethylene Polymers, Patent No. 2,752,321 (G. W. Heller, assignor to E. I. duPont deNemours & Co.) The method for lubricating particulate polytetrafluoroethylene and improving the extrudability thereof which comprises admixing particles consisting essentially of polytetrafluoroethylene with from 7 to 45 cc. of lubricating organic liquid per 100 grams of said polytetrafluoroethylene, said lubricating organic liquid consisting essentially of hydrocarbon oil, until a non-uniform free-flowing mass of powder and lubricant is formed, and thereafter compressing the said mass into a confining space under a pressure of at least 50 lbs./sq.in. until the said lubricant becomes uniformly distributed through the mass as a result of the said compression, whereby a pasty mass which can be readily extruded is obtained, said lubricating organic liquid having a viscosity within the range of from 1 to 100 centipoises.

Oil-Soluble Surface Active Composition, Patent No. 2,753,303 (G. E. Barker, assignor to Atlas Powder Co.) An oil-soluble surface active composition comprising at least 50% by weight of a polyoxyethylene ether of sorbitan tritall oil ester containing from 10 to 50 oxyethylene groups per mol; and at least 5% by weight of a fatty amine-ethylene oxide condensation product containing from 12 to 20 carbon atoms in the fatty radical and from 2 to 6 oxyethylene groups per mol of amine, the proportion of said condensation product being sufficiently great to render the composition soluble in mineral oil.

Organo-Metallic Derivatives of Phosphorus Sulfide-Hydrocarbon Reaction Products and Lubricants Containing Same, Patent No. 2,753,306 (E. K. Fields, assignor to Standard Oil Co.) A composition consisting essentially of the product resulting from the reaction at a temperature in the range of from about 25 to about 200°F. of (1) hydrogen peroxide, (2) a compound selected from the group consisting of oxides and sulfides molybdenum and vanadium and the salts of molybdic and vanadic acids with weak bases having a dissociation constant no greater than about 1×10^{-3}, which compound is capable of affording an oxide of the respective metal under reaction conditions, and (3) an oil-soluble material obtained by reacting an unneutralized phosphorus sulfide-hydrocarbon reaction product with a compound selected from the group consisting of alcohols, phenols, mercaptans, and thiophenols, said oil-soluble material being prepared at a temperature in the range of from about 150 to about 500°F.; said three components of the reaction being contacted in the following approximate proportions based upon one part of component (2), 1 to 40 parts of component (3), and 0.05 to 4 parts of component (1).

Lubricants Containing Oxidized Hydrocarbon Oils, Patent No. 2,753,307 (E. G. Foehr & F. J. Hanly, assignors to California Research Corp.) A lubricating composition comprising essentially a hydrocarbon oil of lubricating viscosity and an amount of oxidized bright stock containing high molecular weight, resinous oxidation products, sufficient to obtain a concentration in the hydrocarbon oil of from 2 to 25% by weight of the said resinous products, the resin content being determinable by adsorption of the resins on fuller's earth and elution therefrom with benzene-alcohol solvent; said bright stock being substantially free from asphaltenes in the unoxidized state and being oxidized by being contacted with an oxygen-containing gas at a temperature of from 300 to 500°F. for a period of from 7 to 30 hours to produce a product having a viscosity of from 100 to 4000 SSF at 210°F. which contains said high

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molecular weight resinous oxidation products and is substantially free from asphaltenes.

Sulfurized Oil of Improved Color Stability, Patent No. 2,753,332 (H. E. Boomsburg & H. T. Shearer, Jr., assignors to Esso Research & Engineering Co.) The process of sulfurizing an oil selected from the group consisting of mineral and fatty oils to obtain a product of relatively light stable color and high stable transparency which comprises heating said oil to a temperature of at least 300°F. with 5 to 40% by weight, based on the oil, of a sulfurizing agent selected from the group consisting of elemental sulfur and phosphorus sulfides, in the presence of at least 0.2% based on the weight of said oil, of trisodium phosphate.

Silicone Fluids of Improved Lubricity, Patent No. 2,753, 365 (S. W. Kantor & R. C. Osthoff, assignors to General Electric Co.) The process of preparing a silicone fluid of improved lubricity which comprises effecting reaction between (1) a cyclic diorganosiloxane in which at least one of the organo groups is a chloromethyl group and in which the remaining organo groups are methyl and (2) sodium in the presence of an inert solvent.

Production of Lubricating Oils of High Viscosity Index, Patent No. 2,754,254 (S. H. Hastings & A. T. Watson, assignors, by mesne assignments, to Esso Research & Engineering Co.) A method for producing a high viscosity index lubricating oil which comprises separating by adsorption on silica gel a lubricating oil fraction containing paraffinic, single and condensed ring naphthenic and single and condensed ring aromatic components into a first fraction containing predominantly saturated lubricating oil components and a second fraction containing predominantly aromatic lubricating oil components, separating by adsorption on activated alumina the second fraction into a fraction containing single ring aromatic lubricating oil components and a fraction containing condensed ring aromatic lubricating oil components, admixing said single ring aromatic lubricating oil components with said predominantly saturated lubricating oil components and recovering from said admixture a lubricating oil of high viscosity index.

Corrosion-Resistant Electrically Conductive Thread Compound, Patent No. 2,754,266 (R. J. Stegemeier & P. W. Fischer, assignors to Union Oil Co. of California) A pipe thread compound comprising between about 45 and about 65% by weight of an alkali metal petroleum sulfonate, between about 13 and about 49.5% by weight of mineral oil, between about 5 and about 10% by weight of a powdered solid material of 13% by weight of water and between about 0.5% and particle size less than about 0.002 inch, said powdered solid material being selected from the class consisting of powdered heavy metals and powdered oxides and sulfides of heavy metals.

Carbon Black Concentrates, Patent No. 2,754,267 (A. A. Bondi, assignor to Shell Development Co.) A fluid carbon black suspension comprising a refined mineral oil having a viscosity and boiling point in the lubricating and fuel oil range and containing less than about 5% of polar substances reactive with aqueous mercuric chloride, said oil having suspended therein between about 10 and about 40% by weight, of the total suspension, of carbon black particles, the shortest diameter of which is less than about 1 micron average, at least about 10% of the surface area of said particles bearing at least about a unimolecular coating of an oil-soluble hydrolyzed copolymer, the copolymer resulting from the copolymerization of a straight chain alpha-olefin hydrocarbon containing between about 12 and about 30 carbon atoms per

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molecule with between about 0.5 and 5 moles, per mole of alpha-olefin, of a vinyl ester selected from the group consisting of vinyl formate, vinyl acetate, vinyl propionate, vinyl butyrate and vinyl benzoate, said copolymer having a molecular weight between about 4000 and about 15,000.

Lubricating Grease Containing a Metal Salt of Algin, Patent No. 2,754,268 (A. J. Morway & J. H. Bartlett, assignors to Esso Research & Engineering Co.) A lubricating grease comprising a major proportion of a lubricating oil and about 2-40 wt. percent of a carboxylic acid metal salt complex grease thickener containing at least 10 wt. percent of a metal salt of alginic acid and a metal salt of a low molecular weight carboxylic acid, said metal being selected from the group consisting of alkali metals, alkaline earth metals and aluminum.

Additive for Lubricants, Patent No. 2,754,269 (J. I. Wasson & L. A. Mikeska, assignors to Esso Research & Engineering Co.) A lubricant composition comprising a major proportion of lubricating oil and about 0.01 to 5% by weight, based on the total composition, sufficient to improve the anti-wear and anti-rust properties of said lubricant, of free acids obtained by the oxidation of a naphthenic white oil having a high unsulfonatable content, an initial boiling point within the range of about 450 to 770°F. and a viscosity at 100°F. of about 34 to 450 SSU obtained by treating a naphthenic oil with fuming sulfuric acid.

Process for Improving Lubricating Oils, Patent No. 2,755,224 (D. W. Young, B. M. Vanderbilt, D. L. Cottle & A. J. Morway, assignors to Esso Research & Engineering Co.) The process of increasing viscosity and improving the viscosity index of a lubricating oil which consists essentially in mixing 0.1 to 5% by weight of a polyhalogenated C_1-C_2 hydrocarbon into said oil and heating the mixture at a temperature of 175 to 400 C. for 10 minutes to 10 hours.

Halogenated Hydrocarbon - Treated Greases, Patent No. 2,755,249 (D. W. Young, A. J. Morway & H. J. Franklin, assignors to Esso Research & Engineering Co.) The process which comprises preparing a soda-base soap thickened mineral lubricating oil grease of moderate ASTM penetration value and heating said grease with 1 to 5% of its weight of carbon tetrachloride to a temperature between 200 and 350°C. under pressure for a period of 10 minutes to 10 hours to substantially complete reaction in order substantially to harden said grease and materially reduce its ASTM penetration value.

Wide Temperature Range Alkali Metal Grease Containing Excess Alkali Metal Hydroxide, Patent No. 2,755,256 (J. P. Dilworth & O. P. Puryear, assignors to The Texas Co.) A wide temperature range ball and roller bearing grease characterized by high dropping point and good low temperature torque properties comprising a mixture of 15 to 25 per cent alkali metal soaps of a soap-forming material having an iodine number of at least 90, 60 to 80 per cent mineral oil, 1.3 to 2.3 per cent alkali metal hydroxide, said grease having been prepared by incorporating said soap-forming material in said mineral oil, adding to said mixture an amount of alkali metal hydroxide equivalent to the sum of the stoichiometric quantity required for saponification plus the prescribed excess alkali metal hydroxide, saponifying said mixture, raising said mixture to a temperature between 480 to 550°F., digesting the mixture at a temperature between 480 and 550°F. for 2½ to 5 hours, cooling said digested mixture with stirring to a temperature of about 200°F. and drawing said grease.

Rustproofing Compositions, Patent No. 2,756,156 (M. J. Hiler, assignor to The Commonwealth Engineering Co. of Ohio) An improved hydrocarbon oil composition comprising a major amount of a hydrocarbon oil and a minor amount of an ester of a saturated fatty acid of from 8 to 18 carbon atoms with a substance selected from the group consisting of dextran and initially low-substituted dextrans in which the substituent groups initially present are groups other than those derived from said saturated fatty acids and present in an average proportion not greater than about 1.0 such group per anhydroglucopyranosidic unit, the amount of the dextran or initially low-substituted dextran ester being sufficient to impart corrosion-resistant properties to the composition.

Hydrotreating Lubricating Oil to Improve Color & Neutralization Number Using a Platinum Catalyst on Alumina, Patent No. 2,756,183 (W. T. Knox, Jr., assignor to Esso Research & Engineering Co.) The process of producing high quality lubricating oil of improved color and low neutralization number which comprises: treating a lubricating oil having a neutralization number above about 0.5 with hydrogen in contact with a catalyst consisting of about 0.05 to 1.0% of platinum supported on active alumina at controlled hydrogenation conditions selected from the range of 400-700°F., 50-250 p.s.i., and 0.5-5 volumes of liquid feed per volume of catalyst per hour, characterized by a hydrogen consumption of less than about 150 standard cubic feet per barrel, a sulfur reduction which does not exceed about 37%, and an increase in viscosity index which does not exceed about 25.

Amate - Dicarboxylate - Thickened Grease, Patent No. 2,756,213 (J. A.

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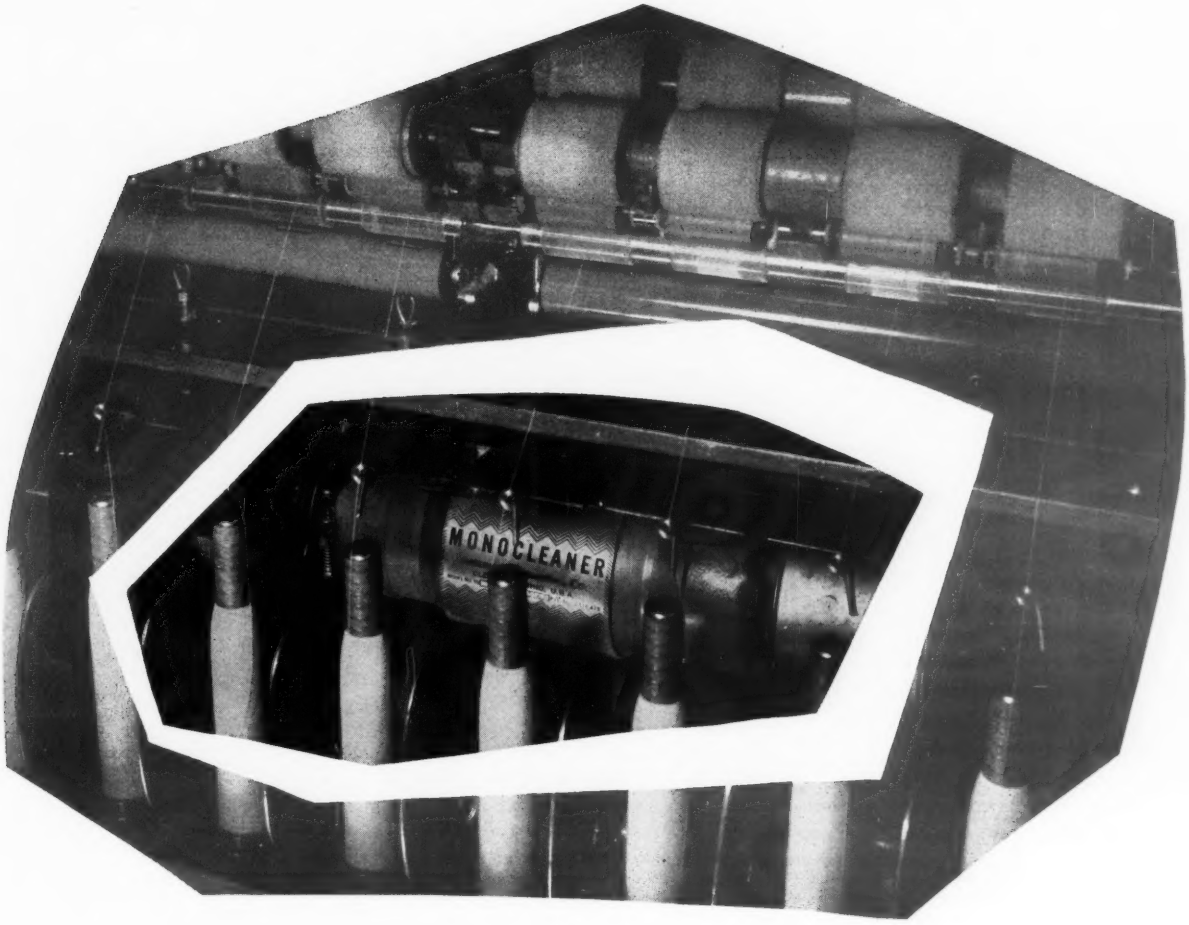

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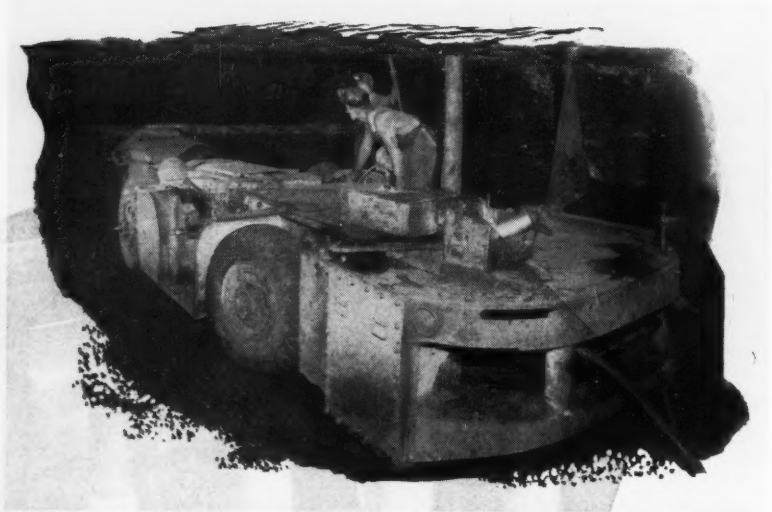

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Dixon, assignor to California Research Corp.) A grease composition comprising a lubricating oil and a grease thickening agent in an amount sufficient to thicken said lubricating oil to the consistency of a grease, said thickening agent being prepared by reacting a dibasic acid containing from 4-10 carbon atoms with an amine containing from 12-8 carbon atoms, wherein the mol ratio of dibasic acid to amine has a value from 1.5 to 5, then neutralizing the resulting dibasic acid-amic acid mixture with an alkali metal hydroxide.

Wax Composition Containing an Oily Butadiene-Styrene Copolymer, Patent No. 2,756,217 (D. W. Young, D. L. Cottle & A. H. Gleason, assignors to Esso Research & Engineering Co.) A wax composition which comprises at least 75% by volume of a hydrocarbon wax of a melting point of about 122 to about 180°F. and a sufficient quantity of a copolymer oil consisting essentially of about 15 to 25% styrene and about 75 to 85% butadiene to impart improved adhesive and tackiness properties thereto; said copolymer having an intrinsic viscosity of about .08 to about .30.

Metal Extrusion Lubricating Composition, Patent No. 2,757,138 (A. Clatot, G. Lemoine & A. Segal, assignors to Societe d'Exploitation des Brevets C L S) A solid, infusible heat-insulating and lubricating composition adapted for interposition between one surface of a metal body to be extruded and an adjacent surface of an extruding assembly therefor, consisting mainly of a heat-insulating, porous, non-abrasive organic substance in a finely divided state, flaked graphite, a higher metal oxide selected from the group consisting of pyrolusite (manganese dioxide), lead dioxide and bismuth tetroxide, and finely divided carbon black, said materials being present in sufficient amounts to produce an exothermic reaction at the extrusion temperature, and a combustible binder selected from the group consisting of natural and synthetic resins, pitch and agglomerating vegetable oils.

(Tech. Abstracts, from p. 207)

Development Center, May 1956; 22 pages. Remarkable thermal stability reported for chlorophenyl phosphates has drawn considerable interest to their possible use as hydraulic fluids for to 0 to 700° F. application. However, tests on three phosphate ester fluids, representing three different classes of chlorophenyl phosphates, showed their thermal stability to exist only in glass apparatus; in the presence of metal, thermal and oxidation stabilities were poor. Flash points, fire points, and foaming temperatures were good, but the viscosity-temperature relationships were unsatisfactory. Since the fluids belonged to three groups of chlorophenyl phosphates and there was little significant difference in their test results, it was concluded that the entire class was undesirable for hydraulic fluid application. Low temperature wear data indicated that the fluids may have possibilities as extreme-pressure additives. (Order No. PB-121446, price 75c)

Fluids, Lubricants, Fuels & Related Materials (3 parts, see below), by M. R. Fenske, et al., Petroleum Laboratory, Pennsylvania State University, for Wright Air Development Center, U. S. Air Force, March 1955.

Part 1 discusses the development of PRL 3313 synthetic lubricants for turbo-prop engines and hydraulic gear boxes, and the further development of raw material and additive sources for PRL 3161-type lubricants. PRL 3313 is a synthetic ester composition containing an acid phosphate in addition to the conventional anti-wear additive, tricresyl phosphate. PRL 3161 is a synthetic ester composition containing 5 per cent tricresyl phosphate. (Order No. PB-121508, 210 pages, price $3.50)

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Research on Boron Polymers (3 parts, see below), by W. L. Ruigh, et al., Rutgers University, for Wright Air Development Center, U. S. Air Force.

Part 1 reviews findings of a three-month survey of literature dealing with inorganic polymers, semi-organic polymers, polymers and rubbers, and the chemistry of boron compounds. Prep-

(Continued on p. 246)

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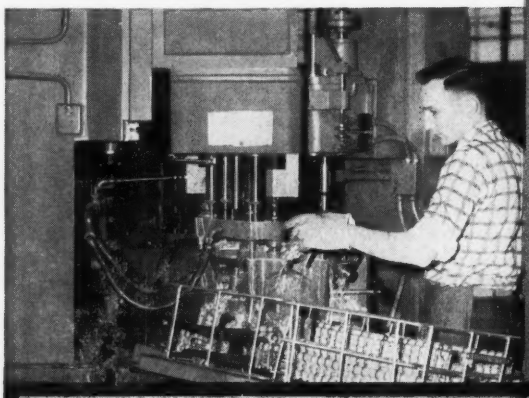

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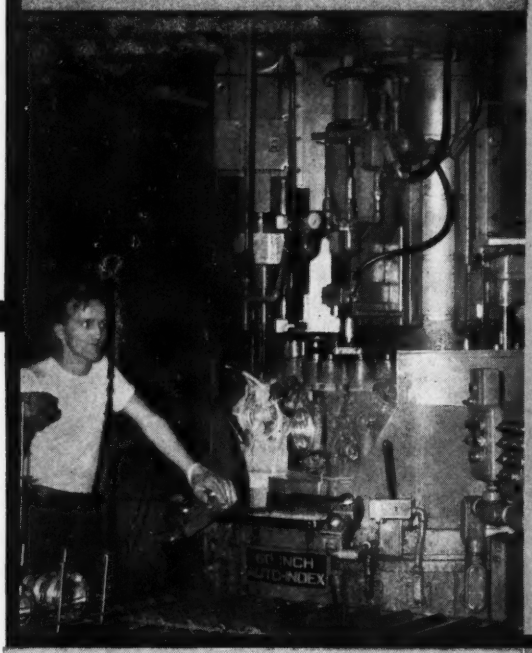

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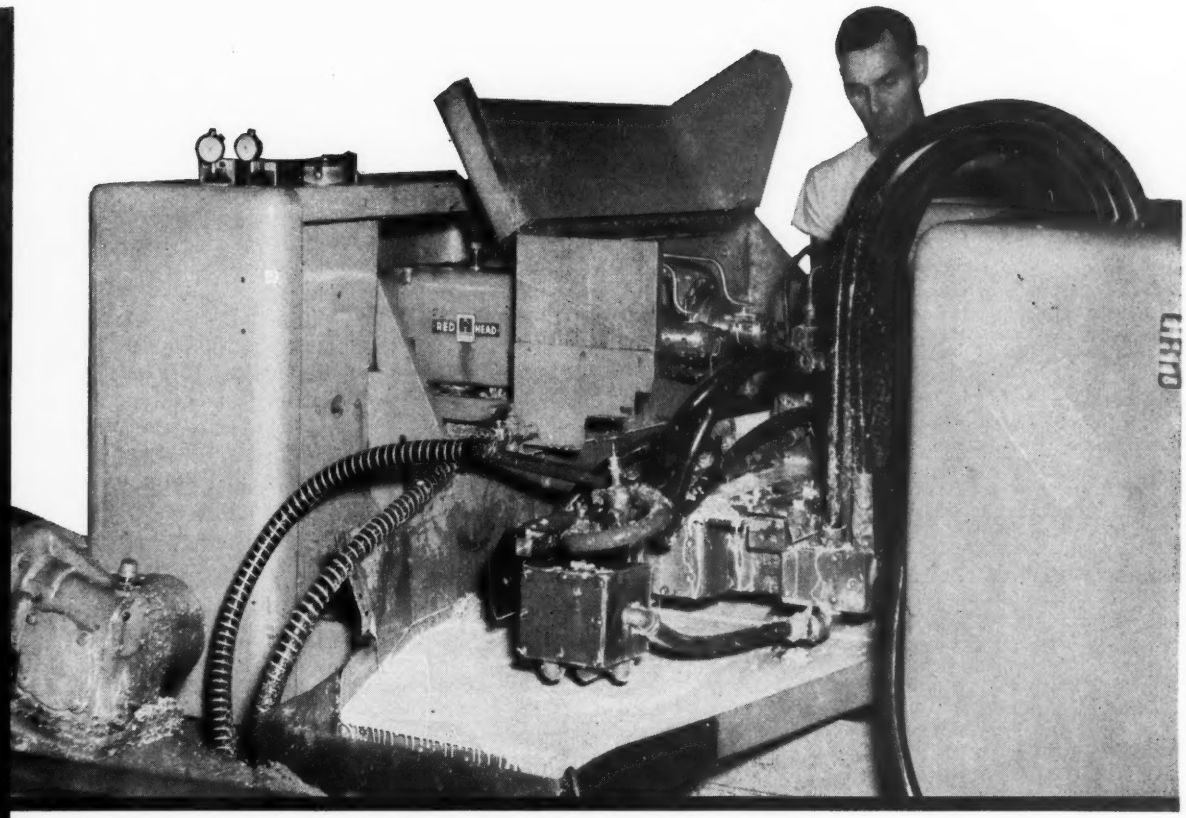

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(Tech. Abstracts, from p. 243)
aration of polymeric boronamides derived from established boronic acids and bi-functional isocyanates was initiated. (Order No. PB-111689, March 1955, 58 pages, price $1.50)

Part 2 reports the synthesis of quadricovalent chelate and quasi-chelate boronic acids and borates. The diethanolamine ester of benzeneboronic acid was prepared and found to be stable to hydrolysis. Allyboronic acid and its esters were synthesized and studied primarily as intermediates for a dimethylaminopropane boronic acid and related compounds. (Order No. PB-111892, May 1955, 85 pages, price $2.25)

Part 3 describes a new, simple and efficient synthesis of boron substituted alkyl and aryl borazoles in which an alkyl or aryl boron dichloride is reacted with ammonia. The basic synthesis is said to be applicable to the preparation of boron containing polymers. Benzeneboronic acid, tri-n-butylborine, butylboron dichloride and phenylboron dichloride were studied as intermediates for the new synthesis. A new catalytic recirculating apparatus for preparing phenylboron dichloride from benzene and boron trichloride by Pace's method is also described. (Order No. PB-121374, May 1956, 47 pages, price $1.25)

(Current Lit., from p. 177)
last year. As in previous annual issues, products are grouped by usage (water-repellents, dielectrics, release agents, etc.), enabling engineers to locate a material by what it does as well as by what it is. Descriptions are brief and factual, with emphasis on charts, tables, and graphs directly comparing various silicones with the materials they are displacing. Heavily illustrated with application photographs. (Dow Corning Corp., Midland, Mich.)

"Zeolite Softeners," a 20-page publication dealing with the necessity for water softening, explains the fundamentals of softening and selection of equipment and zeolites. The bulletin also describes the operation of the Cochrane hydromatic valve for manual or automatic control of the cycling of the process. (Publication 4520, Cochrane Corp., 17th Street below Allegheny, Philadelphia 32, Pa.)

"Properties of Molybdenum Disulfide," designated Bulletin Cdb-5 in the Climax Chemical Data Series, covers the physical properties, thermodynamic properties, electrical and magnetic properties, chemical properties, preparation and uses of molybdenum disulfide (MoS_2). Use of molybdenum as a lubricant additive and as a catalyst are discussed in detail. It is pointed out that the lubricating properties of molybdenum disulfide are based on its laminar structure, and that the compound shows advantages over other solid lubricant additives. On a kinetic-friction apparatus, for example, at room temperature MoS_2 and graphite are about equal in coefficient of friction at low speeds, but MoS_2 has a lower coefficient of friction than graphite at higher speeds. The bulletin lists 25 references to sources of more detailed information on the compound and its properties and uses. (Climax Molybdenum Co., 500 Fifth Ave., New York 36, N. Y.)

"'dag' Colloidal Dispersions for High-Temperature Lubrication," a compilation of current good practice in high-temperature lubrication with colloidal dispersions, contains many brief case histories which describe how 'dag' colloidal graphite (a high-purity electric-furnace graphite processed to colloidal size and dispersed in a wide variety of fluid carriers) is effectively used for general high-temperature lubrication of oven conveyor chains, kiln car wheel bearings, and virtually any other type of mechanical equipment. Applications for 'dag' dispersions in molybdenum disulfide are discussed, and methods presented for increasing die life and obtaining better finish at less cost in such operations as forging, extrusion, stamping, wire-drawing, deep-drawing, and stretch-forming. Numerous product design applications involving pre-assembly coating and utilization of heat-resistant properties of Acheson colloidal dispersions are also cited. (Bulletin No. 423, Acheson Colloids Co., 1630 Washington Ave., Port Huron, Mich.)

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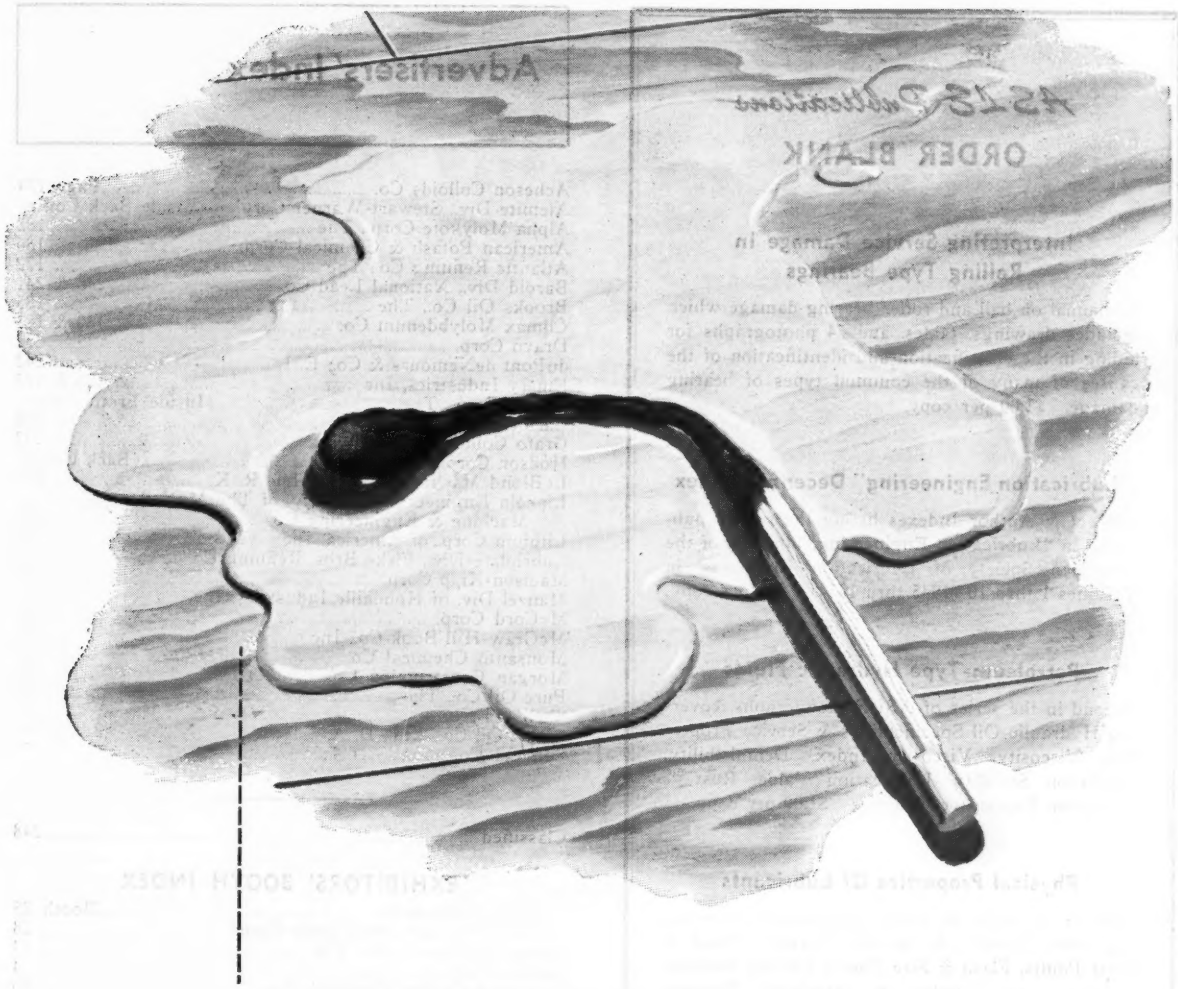

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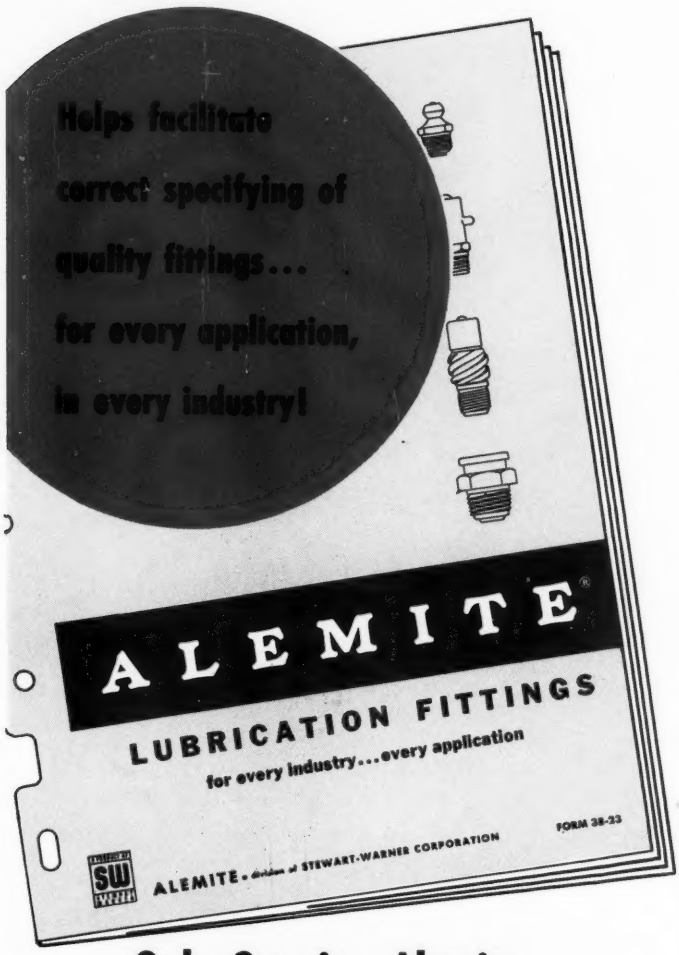
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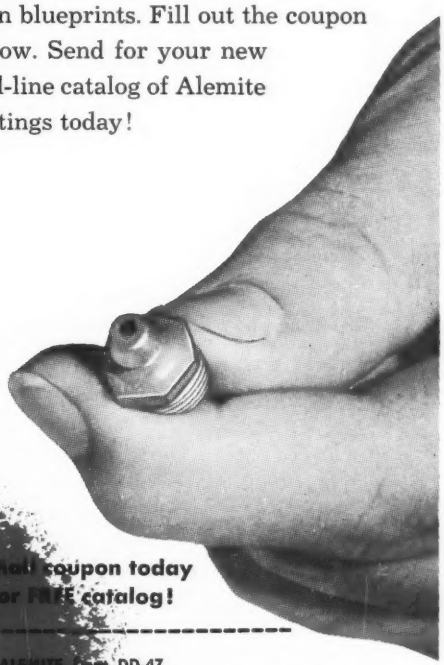

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